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JANUARY, 1865.

CIVIL ENGINEERING.

Essay on the Stadia. By JOHN R. MAYER, C. E.

To the Editor of the Journal of the Franklin Institute.

MR. EDITOR :—I address you an Essay on the *Stadia* with explanations of the principles for computing *graphically* the difference of level and the reduction to the horizon, from observed altitudes and distances obtained with the Stadia. At the same time I beg to make a short retrospection on the subject of *Topography* in order to show the cause of the slow introduction of the *Stadia* in the Topographical Surveys of various countries in Europe.

Topography was not known before the *end of the last century*, for it could not be proper to give that name to a kind of *perspective* lying over the horizontal plane, for the representation of *fancy* crests, or tops of hills, as we see it on the old maps or charts.

The Topographical representation of the ground by means of horizontal curves, was invented by *Ducarla** of Geneva, Switzerland, at the epoch above mentioned, and has since been adopted with success by all the corps of Engineers.

Ducarla's mode was the first step to obtain a true representation of the ground, but required an instrument for the determination of the exact position of the horizontal curves, the use of an ordinary leveling instrument with a chain being too slow an operation for making a Topographical Survey of some extent.

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*See, Puissant, Traité de Topographie, page 226, Paris, 1820.

The idea to measure the distances by a scale and the micrometer of a telescope was proposed by an Italian engineer about 45 years ago, and the name of Stadia (Scale) was given by him to that kind of measure.

The *Stadia* gives but a distance on the inclined plane of Sight, and requires the observation of an altitude for obtaining the difference of level and the reduction to the horizon, which operations are to be done by computation.

To facilitate the work, some engineers made *Tables* for computing the altitudes and the reduction to the horizon, which give a result by interpolation but is a slow and tedious operation.

Such was the progress of the introduction of the *Stadia* for a Topographical and Military Survey, that when, in 1836, the Government of the Swiss Confederacy ordered the Survey of Switzerland, and placed it under the Superintendence of General G. H. Dufour of Geneva.

Before 1836 the Governments of France, Germany, and Italy, had begun the Topographical Survey of their countries, but did not make any improvements in the instruments used for Topography, on account of the facilities they had to make use of all the land Surveys already made. The work of their charts being but to co-ordinate the reductions of the land Survey to a triangulation and to draw the relief of the ground according to some principal elevations obtained from the altitude of trigonometrical points and by a direct leveling, without measuring any distance, the rest of the work being done by sketching. In England the *Ordnance Survey* comprising the land Survey, the Topography was executed in a manner similar to the above mentioned countries.

At the date of 1836, Switzerland had no land Survey, which could be used for the Topographical and Military Survey ordered by the government; it was then necessary to make use of the *Stadia* for the determination of the detail which was to be co-ordinated to a triangulation; consequently it was necessary to unite exactness with rapidity of operation.

Experience of more than 25 years have proved that the Stadia can be used instead of a chain for making a Topographical Survey, which rests on a triangulation.

From the beginning of the Topographical Survey of Switzerland, it appeared obvious that the use of the *Tables* mentioned above, was too slow an operation for the computation of altitudes and reduction to the horizon of points obtained with the Stadia. This want of prompt results led two officers engaged in this Topographical Survey to find a way of making *graphically* these computations. Here I must say that the *principle* and *construction* of the quadrant for the computation of altitudes belong to my old colleague C. Volfschberger of Geneva, and the *principle* and *construction* of the diagram for the reduction to the horizon of any distance measured by *the Stadia* or *the chain*, is my own.

These two modes of computing *graphically* have been used *only* by the assistants of the Federal Survey of Switzerland and have never been yet published.

The *Stadia* has been used in the Topographical Surveys which Col. Richard Delafield, Chief of the U. S. Corps of Engineers, and late Lieut. M. Harrison, U. S. Engineers, entrusted me with in 1850 and 1851; and the use of this instrument and these two modes of graphical computations have been approved by Col. J. D. Graham, U. S. Corps of Engineers for Topographical Surveys made by me under his direction since 1855; and also by Col. W. F. Reynolds, A. D. C. Major Corps of Engineers, U. S. Army, Superintendent of U. S. Lake Survey in the instructions given this year (1864) for the operations of the U. S. Lake Survey.

I now come to explain the use of the Stadia, and also how these quadrants and diagrams are made.

I. *Construction of a Stadia.*

This instrument is constructed on the principle that the distance that separate objects of different dimensions from the observer seeing them under the same visual angle, are proportional to their respective dimensions.

The manner adopted for constructing a *Stadia* is explained as follows, viz:

Let A O B (Fig. 1, Pl. I,) be a visual angle having its vertex O at the eye of the observer, and the sides A O and B O formed by the visual rays which proceed from O and pass through two wires fixed on the diaphragm of a telescope; these sides being produced to the staff C D placed at a known distance O E, will intersect the staff in the two points F and G, which mark a space F G which represent the distance O E.

Consequently if an horizontal line C H equal to O E is measured and the staff C D set up vertically at C in dividing the space F G into as many parts as the distance C H contains units, the scale of the *Stadia* will be known.

The triangle F O G is divided in two right angled triangles F O E and E O G which have both the two sides adjacent to the right angle known; then the angles F and G can be computed.

As the spaces E F and E G depend on the distance of the horizontal wires to the central wire on the plane of the axis of the telescope; if these spaces are not equal then there will be a different value for each angle F and G.

The distance between two points is measured with the Stadia on the inclined plane of sight, therefore the normal position of the Stadia to the axis of the telescope, is an important condition for the true reading of the distance, but knowing the difficulty of holding the staff in such a position, it is better to keep it always vertical, and compute the error of the reading on the Stadia scale.

The length and division of a Stadia are made according to the power of a telescope, and the space between the wires fixed on its diaphragam. Consequently it is necessary to observe that the space A B (Fig. 1, Pl. I,) when produced on the staff C D must not exceed *nine feet* from F to G for the greatest distance given with the telescope, say 2000 feet.

The scale of a Stadia is painted black on a white staff and is divided as shown in Fig. 2. But the space between two divisions of 5 feet is estimated according to the position of the wires.

II. *Correction of the Verticality of the Stadia.*

Let O (Fig. 3, Pl. I,) be the station of the observer, F G the space which represents on the Stadia, C D a distance under the visual angle F O I, which requires a correction so as to be reduced to I K which gives the true distance from O to E, when the Stadia is in a normal position to the central ray O E passing through the axis of the telescope and $LOE = KEF = GEI = \delta$ the observed altitude.

The triangles E G I and E K F not being similar, give the following results.

For the triangle E G I we have, $EG : EI :: \sin I : \sin G$; but $G = 180° - E - I$, hence $\sin G = \sin(E+I)$.

Consequently $EI = EG\left(\dfrac{\sin(E+I)}{\sin I}\right) = EG\dfrac{(\sin E\cos I + \sin I\cos E)}{\sin I}$

$$= EG(\sin E\cot I + \cos E) \quad . \quad . \quad . \quad (1)$$

The triangle E K F gives also:

$$EK = EF(\sin E\cot K + \cos E) \quad . \quad . \quad . \quad (2)$$

Adding (1) and (2) we have

$$IK = FG(\sin E(\cot I + \cot K) + \cos E) \quad . \quad (3)$$

The angle E or δ being small, its sine is also small. The angles I K are both very near of 90°, consequently their cotangent is small, and compared to the value of cos E or cos δ, the product of these two trigonometrical lines can be omitted.

Then by eliminating these small values and representing F G by l we have

$$IK = l\cos\delta \quad . \quad . \quad (4)$$

which is the formula for the true reading on the Stadia corrected for the verticality of any distance on the inclined plane of sight.

The repetition of a distance on the Stadia may be obtained easily by taking many readings at different altitudes and noting each time the value of δ, δ', δ'', δ''', &c., the mean of these observations applied to (4) will be the exact distance O E corrected of the verticality of the Stadia.

III. *The difference of level between two points,*

is obtained by simply multiplying the sine of the observed altitude by the distance corrected for the verticality of the Stadia, which is to multiply the value of I K by sin δ, consequently h being the difference of level, l the distance given by the Stadia, and δ the observed altitude, we have

$$h = l\sin\delta\cos\delta \quad . \quad . \quad (5)$$

IV. *The reduction to the horizon of any distance given by the Stadia with correction for its verticality*, may be computed with both formulæ.

$$r=l\cos^2\delta \; (6); \quad l-r=l\sin^2\delta \quad . \quad . \quad (7)$$

l being a distance given by the Stadia; δ an observed altitude; and r the same distance reduced to the horizon.

V. *Quadrant for computing the difference of level between two points, with correction for the verticality of the Stadia.*

The formula used is (5).

Principle.

Let Fig. 4, (Pl. I,) an altitude be given and its sine multiplied by its cosine produces a certain angle called x; let the sine of x be A B; if the line A B is produced as to make A C=10 times A B by drawing C D parallel to A O until it intersects the arc A D at D, the line D E will represent the sine of an angle y and will be ten times greater than the sine A B. Now if rather than take on O B the distances to be multiplied by the sine of x, they are taken on the line O D, they will be multiplied by the sine of y and consequently the product will be ten times greater:

Construction of a quadrant: with the table of logarithms it is easy to compute the angles from *two* to *two* minutes and to trace on the quadrant every result (by using a protractor, or the table of chords) until the sine $x\times 10$ = *the radius*. This will be the limit of the first quadrant, or quadrant A.

$$\text{Then, } h=y\times 0{\cdot}1 \quad . \quad . \quad (8)$$

The quadrant B is obtained by subtracting the *radius* from the value in number of the logarithm of the sine $x\times 10$ and finding the value of the logarithm of the remainder in degrees.

$$\text{Then, } h=(y+l)\;0{\cdot}1 \quad . \quad . \quad (9)$$

The quadrant C is obtained by subtracting twice the *radius* and doing for the rest the same operation as for the quadrant B.

$$\text{Then, } h=(y+2\,l)\;0{\cdot}1 \quad . \quad . \quad (10)$$

The quadrant D is also obtained by subtracting three times the *radius* and making the rest of the computation as for the quadrant B or C.

$$\text{Then, } h=(y+3\,l)\;0{\cdot}1 \quad . \quad . \quad (11)$$

The results of these computations are shown in the following tables:

Table I, *for the construction of the Quadrant* A. Fig. 5, Plate I.

Observed altitude.	Value of $x \times 10$ in degs.	Observed altitude.	Value of $x \times 10$ in degs.	Observed altitude.	Value of $x \times 10$ in degs.	Observed altitude.	Value of $x \times 10$ in degs.
0° 02′	0° 20′	1° 32	15°31′	3° 02	31° 54′	4° 32′	51° 59′
04	40	34	15 51 40	04	32 17	34	52 32
06	1 00	36	16 12 30	06	32 41	36	53 04
08	1 20	38	16 33 10	08	33 05	38	53 37
10	1 40	40	16 54	10	33 29	40	54 11
12	2 00	42	17 15	12	33 52	42	54 45
14	2 20	44	17 36	14	34 16	44	55 19
16	2 40	46	17 57	16	34 40	46	55 54
18	3 00	48	18 18	18	35 05	48	56 30
20	3 20	50	18 39	20	35 29	50	57 06
22	3 40	52	19 00	22	35 54	52	57 42
24	4 00	54	19 21	24	36 18	54	58 19
26	4 20	56	19 42	26	36 43	56	58 57
28	4 40	58	20 03	28	37 08	58	59 36
30	5 00	2 00	20 25	30	37 33	5 00	60 15
32	5 20	02	20 46	32	37 57	02	60 55
34	5 40	04	21 07	34	38 23	04	61 36
36	6 01	06	21 29	36	38 48	06	62 18
38	6 21	08	21 50	38	39 14	08	63 01
40	6 41	10	22 12	40	39 39	10	63 45
42	7 01	12	22 33	42	40 05	12	64 30
44	7 21	14	22 55	44	40 31	14	65 16
46	7 41	16	23 17	46	40 57	16	66 04
48	8 02	18	23 38	48	41 24	18	66 53
50	8 22	20	24 00	50	41 50	20	67 44
52	8 42	22	24 22	52	42 17	22	68 37
54	9 02	24	24 44	54	42 44	24	69 33
56	9 22	26	25 06	56	43 11	26	70 29
58	9 43	28	25 28	58	43 38	28	71 30
1 00	10 03	30	25 50	4 00	44 06	30	72 34
02	10 23	32	26 12	02	44 33	32	73 41
04	10 43 36	34	26 35	04	45 01	34	74 54
06	11 04	36	26 57	06	45 29	36	76 12
08	11 24 20	38	27 19	08	45 58	38	77 39
10	11 44 44	40	27 42	10	46 26	40	79 17
12	12 05	42	28 04	12	46 55	42	81 13
14	12 25 30	44	28 27	14	47 24	43	82 22
16	12 46	46	28 50	16	47 54	44	83 43
18	13 06 34	48	29 12	18	48 24	45	85 27
20	13 27	50	29 35	20	48 53	46	88 37
22	13 47 40	52	29 58	22	49 24		
24	14 08 15	54	30 21	24	49 54		
26	14 29	56	30 44	26	50 25		
28	14 49 30	58	31 07	28	50 56		
30	15 10 10	3 00	31 30	30	51 28		

Limit of the Quadrant A = 5° — 46′ — 06″.

TABLE II, *for the Construction of the Quadrant* B. Fig. 6, Plate I.

Observed altitude.	Value of $x\times10-R$, in degs.	Observ'd altitude.	Value of $x\times10-R$, in degs.	Observ'd altitude.	Value of $x\times10-R$, in degs.	Observ'd altitude.	Value of $x\times10-R$, in degs.
5° 48′	0° 18′	7° 20′	15° 25′	8° 52′	31° 32′	10° 24′	50° 51′
50	0 38	22	15 45	54	31 54	26	51 21
52	0 58	24	16 06	56	32 16	28	51 51
54	1 17	26	16 26	58	32 39	30	52 21
56	1 37	28	16 46	9 00	33 02	32	52 51
58	1 56	30	17 06	02	33 25	34	53 22
6 00	2 16	32	17 26	04	33 47	36	53 54
02	2 36	34	17 46	06	34 10	38	54 26
04	2 55	36	18 07	08	34 33	40	54 59
06	3 15	38	18 27	10	34 56	42	55 31
08	3 35	40	18 48	12	35 20	44	56 04
10	3 54	42	19 08	14	35 43	46	56 38
12	4 14	44	19 28	16	36 06	48	57 12
14	4 33	46	19 49	18	36 30	50	57 47
16	4 53	48	20 09	20	36 54	52	58 22
18	5 12	50	20 30	22	37 18	54	58 57
20	5 32	52	20 50	24	37 41	56	59 34
22	5 51	54	21 11	26	38 05	58	60 11
24	6 11	56	21 31	28	38 29	11 00	60 49
26	6 31	58	21 52	30	38 53	02	61 27
28	6 50	8 00	22 13	32	39 18	04	62 06
30	7 10	02	22 34	34	39 42	06	62 46
32	7 30	04	22 55	36	40 07	08	63 27
34	7 49	06	23 16	38	40 32	10	64 09
36	8 09	08	23 37	40	40 57	12	64 52
38	8 29	10	23 58	42	41 22	14	65 36
40	8 49	12	24 19	44	41 47	16	66 21
42	9 08	14	24 40	46	42 12	18	67 08
44	9 28	16	25 01	48	42 38	20	67 57
46	9 47	18	25 22	50	43 03	22	68 47
48	10 07	20	25 43	52	43 29	24	69 39
50	10 27	22	26 05	54	43 55	26	70 33
52	10 46	24	26 26	56	44 21	28	71 29
54	11 06	26	26 47	58	44 48	30	72 29
56	11 26	28	27 09	10 00	45 14	32	73 32
58	11 46	30	27 30	02	45 41	34	73 39
7 00	12 06	32	27 52	04	46 08	36	75 51
02	12 26	34	28 14	06	46 36	38	77 10
04	12 46	36	28 35	08	47 03	40	78 38
06	13 06	38	28 57	10	47 30	42	80 18
08	13 25	40	29 19	12	47 58	43	81 16
10	13 45	42	29 41	14	48 27	44	82 20
12	14 05	44	30 03	16	48 55	45	83 35
14	14 25	46	30 25	18	49 23	46	85 08
16	14 46	48	30 46	20	49 52	47	87 32
18	15 05	50	31 09	22	50 22		

Limit of the Quadrant B=11°—47′—21″.

TABLE III, *for the Construction of the Quadrant* c. Fig. 7, Plate I.

Observ'd altitude.	Value of $x \times 10-2\text{R}$, in degs.	Observ'd altitude.	Value of $x \times 10-2\text{R}$, in degs.	Observ'd altitude.	Value of $x \times 10-2\text{R}$ in degs.	Observ'd altitude.	Value of $x \times 10-2\text{R}$, in degs.
11° 48′	0° 06′	13° 34′	16° 17′	15° 20′	33 23	17° 06′	54° 08′
50	0 24	36	16 35	22	33 43	08	54 37
52	0 43	38	16 54	24	34 04	10	55 05
54	1 01	40	17 13	26	34 25	12	55 34
56	1 19	42	17 31	28	34 46	14	56 03
58	1 38	44	17 50	30	35 07	16	56 33
12 00	1 56	46	18 08	32	35 28	18	57 03
02	2 14	48	18 27	34	35 49	20	57 34
04	2 32	50	18 46	36	36 10	22	58 05
06	2 51	52	19 05	38	36 31	24	58 36
08	3 09	54	19 23	40	36 53	26	59 08
10	3 27	56	19 42	42	37 14	28	59 40
12	3 45	58	20 01	44	37 35	30	60 13
14	4 04	14 00	20 20	46	37 57	32	60 46
16	4 22	02	20 38	48	38 19	34	61 20
18	4 40	04	20 57	50	38 40	36	61 54
20	4 58	06	21 16	52	39 02	38	62 29
22	5 16	08	21 35	54	39 23	40	63 05
24	5 34	10	21 54	56	39 45	42	63 42
26	5 53	12	22 13	58	40 08	44	64 19
28	6 11	14	22 32	16 00	40 31	46	64 56
30	6 30	16	22 51	02	40 53	48	65 36
32	6 48	18	23 10	04	41 16	50	66 16
34	7 06	20	23 29	06	41 38	52	66 56
36	7 25	22	23 49	08	42 01	54	67 38
38	7 43	24	24 08	10	42 24	56	68 21
40	8 01	26	24 27	12	42 47	58	69 06
42	8 19	28	24 46	14	43 10	18 00	69 52
44	8 37	30	25 06	16	43 33	02	70 40
46	8 55	32	25 25	18	43 56	04	71 29
48	9 14	34	25 44	20	44 19	06	72 22
50	9 32	36	26 03	22	44 43	08	73 17
52	9 50	38	26 23	24	45 07	10	74 11
54	10 08	40	26 43	26	45 31	12	75 15
56	10 27	42	27 02	28	45 55	14	76 22
58	10 45	44	27 22	30	46 19	16	77 32
13 00	11 03	46	27 41	32	46 43	18	78 51
02	11 22	48	28 01	34	47 08	20	80 20
04	11 41	50	28 21	36	47 33	21	81 09
06	11 59	52	28 41	38	47 58	22	82 03
08	12 17	54	29 00	40	48 23	23	83 05
10	12 35	56	29 20	42	48 48	24	84 18
12	12 54	58	29 40	44	49 13	25	85 53
14	13 12	15 00	30 00	46	49 38	26	88 47
16	13 30	02	30 20	48	50 04		
18	13 49	04	30 40	50	50 31		
20	14 07	06	31 00	52	50 57		
22	14 25	08	31 20	54	51 24		
24	14 44	10	31 40	56	51 50		
26	15 03	12	32 01	58	52 17		
28	15 21	14	32 21	17 00	52 45		
30	15 40	16	32 42	02	53 12		
32	15 58	18	33 02	04	53 40		

Limit of the Quadrant c = 18°—26′—05″.

TABLE IV, *for the Construction of the Quadrdnt* D. Fig. 8, Plate I.

Observ'd altitude.	Value of x×10—3R, in degs.	Observ'd altitude.	Value of x×10–3R, in degs.	Observ'd altitude.	Value of x×10—3R, in degs.	Observ'd altitude.	Value of x×10—3R, in degs.
18° 28′	0° 15′	20° 10′	13° 40′	21° 52′	27° 10′	23° 34′	41° 40′
30	0 31	12	13 55	54	27 26	36	41 58
32	0 47	14	14 11	56	27 42	38	42 16
34	1 03	16	14 27	58	27 59	40	42 35
36	1 19	18	14 42	22 00	28 15	42	42 53
38	1 35	20	14 58	02	28 31	44	43 11
40	1 51	22	15 14	04	28 47	46	43 30
42	2 07	24	15 29	06	29 04	48	43 48
44	2 23	26	15 45	08	29 20	50	44 07
46	2 39	28	16 01	10	29 36	52	44 26
48	2 55	30	16 17	12	29 53	54	44 45
50	3 11	32	16 32	14	30 10	56	45 04
52	3 27	34	16 48	16	30 26	58	45 23
54	3 42	36	17 04	18	30 43	24 00	45 42
56	3 58	38	17 20	20	31 00	02	46 01
58	4 14	40	17 35	22	31 16	04	46 21
19 00	4 29	42	17 51	24	31 33	06	46 40
02	4 45	44	18 07	26	31 49	08	46 59
04	5 01	46	18 23	28	32 06	10	47 19
06	5 17	48	18 38	30	32 23	12	47 38
08	5 33	50	18 54	32	32 40	14	47 58
10	5 48	52	19 10	34	32 57	16	48 18
12	6 04	54	19 26	36	33 13	18	48 38
14	6 20	56	19 42	38	33 30	20	48 58
16	6 36	58	19 58	40	33 47	22	49 18
18	6 51	21 00	20 13	42	34 04	24	49 39
20	7 07	02	20 29	44	34 21	26	49 59
22	7 23	04	20 45	46	34 38	28	50 20
24	7 39	06	21 01	48	34 55	30	50 40
26	7 55	08	21 17	50	35 12	32	51 00
28	8 10	10	21 33	52	35 29	34	51 21
30	8 26	12	21 49	54	35 46	36	51 43
32	8 42	14	22 05	56	36 03	38	52 04
34	8 58	16	22 20	58	36 20	40	52 26
36	9 13	18	22 36	23 00	36 38	42	52 47
38	9 29	20	22 52	02	36 55	44	53 09
40	9 45	22	23 08	04	37 12	46	53 31
42	10 00	24	23 24	06	37 30	48	53 52
44	10 16	26	23 40	08	37 48	50	54 14
46	10 31	28	23 56	10	38 05	52	54 36
48	10 47	30	24 13	12	38 23	54	54 59
50	11 03	32	24 29	14	38 40	56	55 21
52	11 18	34	24 45	16	38 58	58	55 44
54	11 34	36	25 00	18	39 15	25 00	56 08
56	11 50	38	25 16	20	39 33	02	56 31
58	12 06	40	25 32	22	39 52	04	56 54
20 00	12 21	42	25 49	24	40 09	06	57 17
02	12 37	44	26 05	26	40 27	08	57 41
04	12 53	46	26 21	28	40 45	10	58 05
06	13 08	48	26 37	30	41 03	12	58 29
08	13 24	50	26 53	32	41 22	14	58 54

TABLE IV, *Continued.*

Observ'd altitude.	Value of $x \times 10 - 3\text{R}$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3\text{R}$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3\text{R}$, in degs.	Observ'd altitude.	Value of $x \times 10 - 3\text{R}$, in degs.
25° 16′	59° 19′	25° 38′	64° 12′	26° 00′	70° 03′	26° 22′	78° 16′
18	59 44	40	64 41	02	70 40	24	79 18
20	60 09	42	65 10	04	71 17	26	80 26
22	60 35	44	65 40	06	71 56	28	81 46
24	61 00	46	66 11	08	72 37	29	82 27
26	61 26	48	66 42	10	73 18	30	83 19
28	61 53	50	67 13	12	74 03	31	84 13
30	62 20	52	67 46	14	74 48	32	85 20
32	62 47	54	68 19	16	75 35	33	86 47
34	63 15	56	68 53	18	76 25		
36	63 44	58	69 27	20	77 18		

Limit of the Quadrant D=26° 33′ 41″.

In order to obtain a result with these quadrants, which can approximate to less than *a tenth of an unit* it will be necessary to make the *radius* of each quadrant of *about six inches.*

In tracing these quadrants on both sides of a sheet of paste-board a complete set will require only two sheets.

It may happen that in the course of a topographical survey some distances have been measured with a chain according to the inclination of the ground ; in that case the formula for computing an altitude would be

$$h = l \sin \delta \quad . \quad . \qquad (12)$$

and quadrants could be made on a principle similar to the above mentioned.

VI. *Diagram for reducing to the horizon any distance given by the Stadia, with correction for its verticality.*

The formula used for computing with the table of logarithms is (6); but for *graphical* computation the formula (7) is preferred.

Principle : The versed sine of an arc corresponding to the expression *sin*^{2} δ being found from the table of logarithms, its value in number is increased *one thousand times*, from 0° to 1° 50′; *one hundred times* from 1° 50′ to 5° 45′; and *ten times* from 5° 45′ to 23°. This being the limit of the diagrams, for it is very seldom that so great an altitude as 23° be taken in topography, on account of the discrepancy which observations with such a slope would produce.

In order to avoid a confusion of lines, a diagram is made for each series or multiple of versed sine.

Construction of a diagram: Fig. 9, Pl. I. Draw a line A B of any given length (six inches), and from its extremities A and B trace the lines A D, B C at right angles to it. Divide each of the lines A D and B C in the same number of equal parts (say twenty parts to one inch) and draw from each division parallel lines as C D, E F, G H, &c.

The line A B being taken as a radius or an unit, make a *scale of versed sines* on the line B C and draw lines from A to each extremity of versed sine as A I, A K, A L, &c.; this done the diagram for the reduction to the horizon is complete.

Now to make use of the diagram; suppose a distance M N corresponding to a certain altitude which is represented by the angle B A K, its versed sine will be N O, for it is obvious that the versed sine is found by comparing together the similar triangles K A B and N A O; A O being equal to M N.

The value of the versed sine increased *one thousand times* will make the first diagram, or diagram A; the versed sine multiplied by *one hundred* will give the diagram B; and the versed sine multipled by *ten* will compose the diagram C.

Consequently the versed sine N O will be *one thousand*, or *one hundred* or *ten times* greater according to which series of diagrams it belongs to; and using a general expression, by calling the distance M N $=l$, and the versed sine N O $=x$, the reduction to the horizon of any distance will be

$l - x \times 0{\cdot}001$ for any versed sine contained in the diagram A;
$l - x \times 0{\cdot}01$ " " " diagram B;
$l - x \times 0{\cdot}1$ " " " diagram C;

The diagrams A and B, with a radius of about 6 inches, give a result which can approximate to a *hundredth of an unit* and the diagram C, to a *tenth of an unit.*

In tracing the diagrams (Fig 13, Pl.I) A and B on one side of a sheet of paste-board, as shown in the Fig. 13, and the diagram C on the other side of the same sheet; the three diagrams will require only one sheet.

If distances measured with a chain are to be reduced to the horizon, the formula will be

$$r = l \cos \delta \qquad . \qquad . \qquad (13)$$

and diagrams can be made on the same principle as the one above mentioned.

It results from these explanations on the Stadia, that a telescope adjusted with a micrometer having a movable wire, cannot give an exact distance, unless the staff used as *Stadia* be always set up in a normal position in regard to the axis of the telescope.

The following Tables contain the value of versed sine corresponding to each series of these diagrams.

TABLE V, *for the Diagram* A. Fig. 10, Plate I.

Observ'd altitude.	Value of $x\times1000$.	Observ'd altitude.	Value of $x\times1000$.	Observ'd altitude.	Value of $x\times1000$.	Observ'd altitude.	Value of $x\times1000$.
0° 02′	·0005	0° 30′	·0761	0° 58′	·2846	1° 26′	·6257
04	·0014	32	·0876	1 00	·3048	28	·6550
06	·0033	34	·0977	02	·3251	30	·6850
08	·0056	36	·1095	04	·3468	32	·7158
10	·0084	38	·1220	06	·3684	34	·7477
12	·0120	40	·1354	08	·3904	36	·7798
14	·0166	42	·1430	10	·4144	38	·8125
16	·0216	44	·1620	12	·4389	40	·8460
18	·0277	46	·1791	14	·4630	42	·8802
20	·0336	48	·1948	16	·4884	44	·9150
22	·0409	50	·2114	18	·5148	46	·9505
24	·0488	52	·2288	20	·5414	48	·9868
26	·0570	54	·2468	22	·5691	50	1·0236
28	·0663	56	·2653	24	·5970		

The altitude 1° 50′ is the limit of the Diagram A.

TABLE VI, *for the Diagram* B. Fig. 11, Plate I.

Observ'd altitude.	Value of $x\times100$.	Observ'd altitude.	Value of $x\times100$.	Observ'd altitude.	Value of $x\times100$.	Observ'd altitude.	Value of $x\times100$.
1° 50′	·10236	2° 50′	·2443	3° 50′	·4465	4° 50′	·7099
55	·11184	55	·2589	55	·46657	55	·7346
2 00	·12178	3 00	·2739	4 00	·4866	5 00	·7596
05	·13218	05	·2893	05	·5070	05	·7850
10	·14293	10	·30514	10	·5279	10	·8109
15	·15416	15	·32143	15	·5492	15	·8373
20	·16575	20	·33809	20	·5709	20	·8639
25	·1778	25	·35516	25	·5930	25	·8911
30	·19025	30	·3727	30	·6156	30	·9187
35	·20316	35	·3906	35	·6385	35	·9464
40	·21646	40	·4089	40	·6619	40	·9749
45	·23018	45	·4277	45	·6857	45	1·0038

The altitude 5° 45′ is the limit of the Diagram B.

TABLE VII, *for the Diagram* c. Fig. 12, Plate I.

Observ'd altitude.	Value of $x\times10$.	Observ'd altitude.	Value of $x\times10$.	Observ'd altitude.	Value of $x\times10$.	Observ'd altitude.	Value of $x\times10$.
5° 45′	·10038	10° 05′	·3066	14° 25′	·6199	18° 45′	1·0332
50	·1033	10	·3116	30	·6268	50	1·0421
55	·1063	15	·3167	35	·6340	55	1·0510
6 00	·1093	20	·3218	40	·6411	19 00	1·0599
05	·1123	25	·3269	45	·6483	05	1·0689
10	·1154	30	·3321	50	.6554	10	1·0779
15	·1186	35	·3374	55	·6636	15	1·0869
20	·1217	40	·3426	15 00	·6698	20	1·0960
25	·1249	45	.3479	05	·6772	25	1·10514
30	·1282	50	·3533	10	.6845	30	1·1143
35	·1315	55	·3587	15	·6918	35	1·1234
40	·1348	11 00	·3641	20	·6993	40	1·1326
45	·1382	05	·3696	25	·7067	45	1·1418
50	·1416	10	·3751	30	·7140	50	1·15115
55	·1450	15	·3806	35	·7217	55	1·16045
7 00	·1485	20	·3862	40	·7292	20 00	1·16978
05	·1521	25	·3918	45	·7368	05	1·17915
10	·1558	30	·3975	50	·7444	10	1·18854
15	·1593	35	·4032	55	·75207	15	1·19798
20	·1630	40	·4089	16 00	·7598	20	1·2074
25	·1667	45	·4147	05	·7675	25	1·2169
30	·1705	50	·4206	10	·7753	30	1·2265
35	·1742	55	·4264	15	·7831	35	1·2360
40	·1778	12 00	·4323	20	·7909	40	1·2456
45	·1819	05	·4382	25	·7987	45	1·2552
50	·1858	10	·4442	30	·8066	50	1·2649
55	·1897	15	·4502	35	·8146	55	1·2745
8 00	·1937	20	.4563	40	·8225	21 00	1·2843
05	·1977	25	·4623	45	·8306	05	1·2940
10	·2018	30	.4685	50	·8386	10	1·3038
15	·2059	35	·4747	55	·8467	15	1·3136
20	·2101	40	·4808	17 00	·8548	20	1·3234
25	·2143	45	·4871	05	·8629	25	1·3333
30	·2185	50	·4934	10	·87115	30	1·3432
35	·2228	55	·4997	15	·8794	35	1·3532
40	·22705	13 00	·5061	20	·8876	40	1·3631
45	·2314	05	·5124	25	·8959	45	1·3731
50	·2358	10	·5189	30	·9042	50	1·3832
55	·2403	15	·5254	35	·9126	55	1·3932
9 00	·2448	20	·5319	40	·9210	22 00	1·4033
05	·2493	25	·5384	45	·9294	05	1·4134
10	·2538	30	·5450	50	·9379	10	1·4235
15	·2584	35	·5516	55	·9464	15	1·4337
20	·2631	40	·5582	18 00	·9549	20	1·4439
25	·2677	45	·5649	05	·9635	25	1·4540
30	·2724	50	·5717	10	·9721	30	1·4640
35	·2772	55	·5785	15	·9807	35	1·4740
40	·2820	14 00	·5853	20	·9894	40	1·4850
45	·2868	05	·5921	25	·9981	45	1·4950
50	·2917	10	·5990	30	1·0068	50	1·5058
55	·2966	15	·6059	35	1·0156	55	1·5160
10 00	·3015	20	·6129	40	1·0244	23 00	1·5267

The altitude 23° is the limit of the Diagram c.

The same case occurs when the Stadia is held horizontally; it ought to be in a normal direction to the telescope, for it could be oblique to the axis of the telescope, and still be horizontal.

When a topographical survey is executed with a plane-table, the altitudes of points observed with the vertical circle of its alidade, may be computed *graphically* by using a *scale of tangents*, from the horizontal distances determined on the plane-table sheet. The telescope of its alidade may also be adjusted for the Stadia, in case the points cannot be determined by intersections.

In leveling ground which is nearly flat, it has been found very expedient to use the Stadia together with a *self-reading* staff or rod. The Stadia gives the *distance* and the self-reading rod the *difference of level*, and thus avoids observing any altitude.

When a theodolite is used for such a leveling, the error of collimation of its vertical circle is to be ascertained, for adjusting the axis of its telescope to a horizontal plane.

A spirit-level can also be used by adjusting its telescope for the Stadia.

The same staff can be used by marking the scale of the Stadia on one side and the divisions of the self-reading staff or rod (in feet and decimals of a foot) on the other side.

DETROIT, 1864.

On the Effect of Impact, Vibratory Action, and long continued changes of Load on Wrought Iron Girders. By DR. FAIRBAIRN.

From the London Mechanics' Magazine, Nov., 1864.

The defects and break-downs which followed the first successful application of wrought iron to bridge-building led to doubts and fears on the part of engineers; and many of them contended for eight, and even ten times the heaviest load as the safe margin of strength. Others, and among them the late Mr. Brunel, fixed a lower standard; and I believe that gentleman was prepared in practice to work up to one-third or two-fifths of the ultimate strength of the weight that would break the bridge. Ultimately it was decided by the authorities of the Board of Trade, but from what data I am not informed, that no wrought iron bridge should with the heaviest load exceed a strain of 5 tons per square inch. Now on what principle this standard was established does not appear; and on application to the Board of Trade the answer is, that "The Lords Commissioners of Trade require that all future bridges for railway traffic shall not exceed a strain of 5 tons per square inch."

The requirement of 5 tons per square inch on the part of the Board of Trade is not sufficiently definite to secure in all cases the best form of construction. It is well known that the powers of resistance to strain are widely different with wrought iron, according as we apply a force of tension or compression; it is even possible so to disproportion the top and bottom areas of a wrought iron girder calculated to

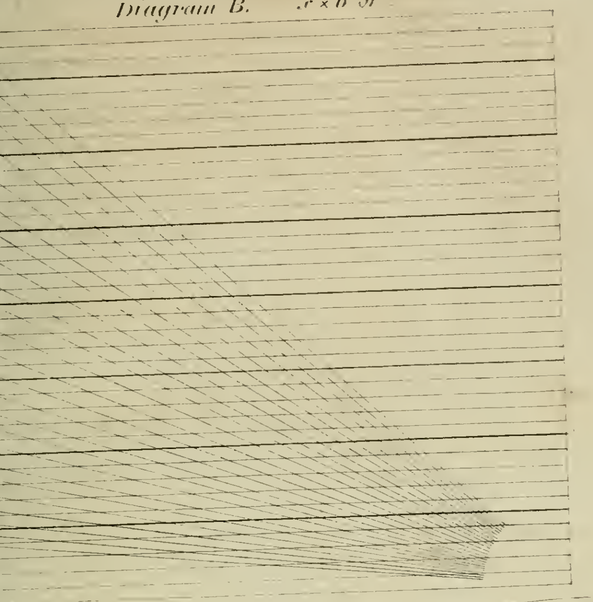


Diagram B.

Fig. 11.

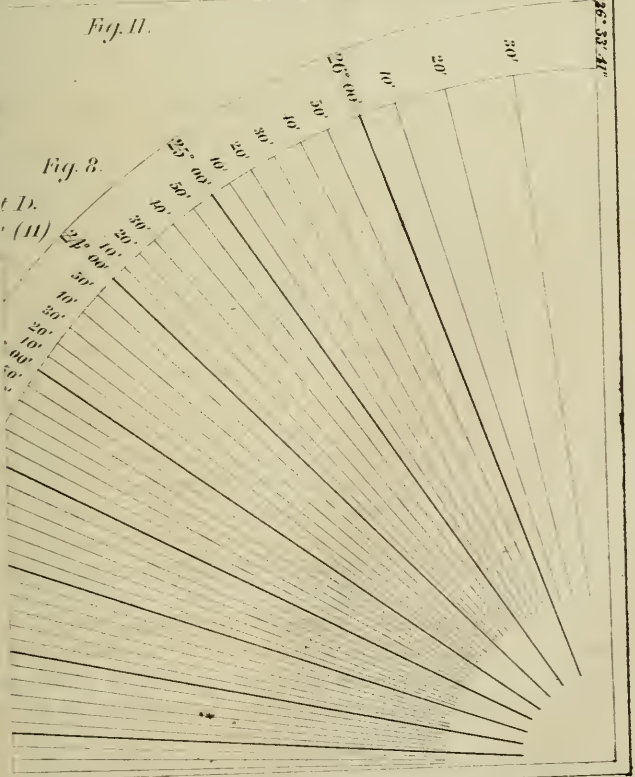
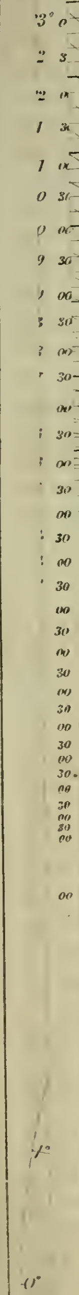


Fig. 8.



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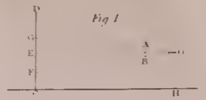


Fig 1

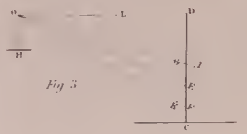


Fig 3

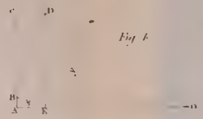


Fig 4

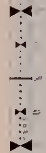


Fig 2

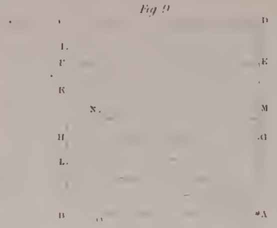


Fig 9

Quadrant A
h = v × 0·1 (8

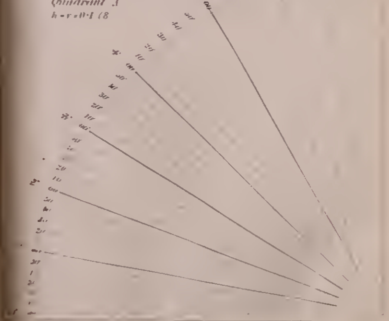


Fig 5

Quadrant B
h = (v − 1) 0·1 (9)

Fig 6

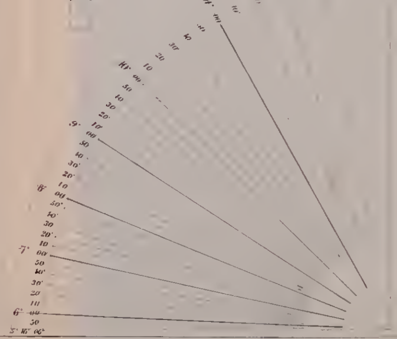
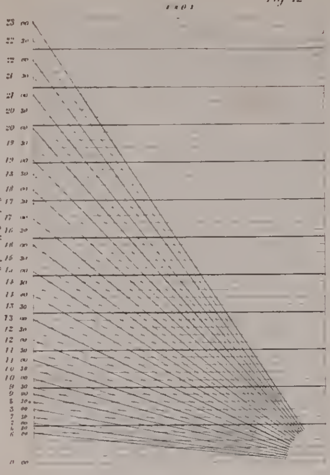


Diagram C

Fig 12



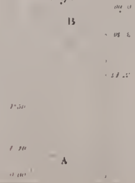


Fig 13

Diagram A

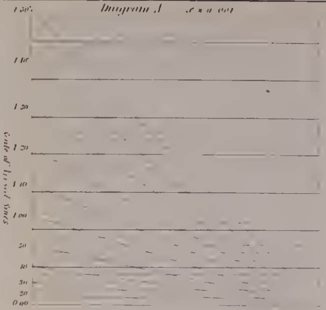


Fig 10

Diagram B

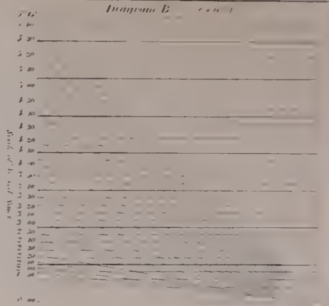


Fig 11

Quadrant C.
h = (v − 21) 0·1 (10)

Fig 7.

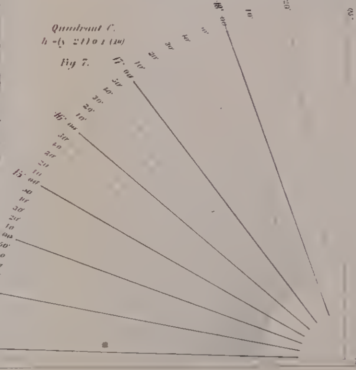
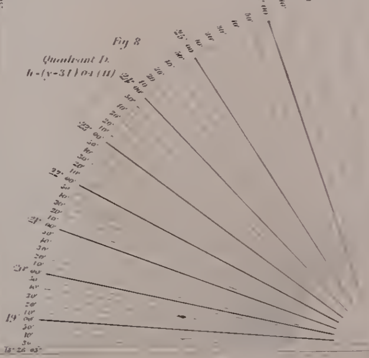


Fig 8

Quadrant D.
h = (v − 31) 0·1 (11)



support six times the rolling load, as to cause it to yield with little more than half the ultimate strain, or ten tons on the square inch. For example, in wrought iron girders with solid tops it requires the sectional area in the top to be nearly double that of the bottom, to equalize the two forces of tension and compression ; and unless these proportions are strictly adhered to in the construction, the 5-ton strain per square inch is an error which may lead to dangerous results. Again, it was ascertained from direct experiment that double the quantity of material in the top of a wrought iron girder was not the most effective form for resisting compression. On the contrary it was found that little more than half the sectional area was required, and, when converted into rectangular cells, was in its powers of resistance equivalent to double the area when formed of a solid plate. This discovery was of great value in the construction of tubes and girders of wide span, as the weight of the structure itself (which increases as the cubes, and the strength only as the squares) forms an important part of the load to which it is subjected. On this question it was evident that the requirement of the Board of Trade cannot be applied in both cases, and is therefore ambiguous as regards its application to different forms of structure. In the 5-ton per square inch there is not a word said about the dead weight of the bridge ; and we are not informed whether the breaking weight was to be so many times the applied weight *plus* the multiple of the load, or, in other words, whether it included or deducted the weight of the bridge itself.

These data are wanting in the railway instructions ; and until some fixed principle of construction is determined upon, accompanied by a standard measure of strength, it is in vain to look for any satisfactory result in the erection of road and railway bridges composed entirely of wrought iron.

To arrive at correct results, and to imitate as nearly as possible the strain to which bridges are subjected by the passage of heavy railway trains, an apparatus specially adapted for that purpose was designed to lower the load quickly upon the beam in the first instance, and subsequently to produce a considerable amount of vibration, as the large lever with its load and shackle was left suspended upon it in the second. The apparatus was sufficiently elastic for that purpose.

The beam tested was composed of an iron plate riveted with angle irons 22 feet long, one-eighth of an inch thick and 16 inches deep.

It was supported on two brick piers 20 feet apart. Beneath the bottom flange is fixed a lever, which, by means of a link and shackle, grasps the lower web of the beam close to the fulcrum. This fulcrum, on which the lever oscillates, is formed of a vertical bar, which acts as a standard, and has screw nuts to regulate the height from the cast iron sole plate to the fulcrum. The machinery for lifting the lever and scale consists of a shaft and pulley driven by a water-wheel ; and from this shaft the apparatus for lifting the load is worked by a strap from the pulley on a pinion shaft, which drives a shaft and spur-wheel, giving motion to a connecting rod. This rod has an oblong slot at its lower end, in which the pin at the end of the lever works. From this description it will be seen that, in turning the spur-wheel, the weight is not raised until the bottom of the slot comes in contact with the pin of the lever, when the load is taken entirely off the beam. That being accomplished, the connecting rod descends, when the load is again laid upon the beam and left suspended with a vibratory motion for some seconds, until the remainder of the stroke is completed, when the connecting rod again rises for the succeeding lift. In this way the weights are lifted off and replaced alternately upon the beam at the rate of seven to eight strokes per minute. The apparatus is worked night and day by a water-wheel, and the number of changes are registered by the counter attached to the vertical post.

The girder subjected to vibration in these experiments is a wrought iron plate beam of 20 feet clear span, and of the following dimensions :—

	inches.	
Area of top, 1 plate 4 inches × ½ inch,	2·00	
" 2 angle-irons 2 × 2 × 5-16ths,	2·30	
		4·30
Area of bottom, 1 plate 4 inches × ¼ inch,	1·00	
" 2 angle-irons 2 × 2 × 3-16ths inch,	1·40	
		2·40
Web, 1 plate 15¼ × ⅛		1·90
Total sectional area,		8·60
Depth,	16 inches.	
Weight,	7 cwt. 3 qrs.	
Breaking weight (calculated),	12 tons.	

The beam having been loaded with 6643 ℔s, underwent above half-a-million changes of load, by working continuously for two months, night and day at the rate of about eight changes per minute, without producing any visible alteration, the load was increased from one-fourth to two-sevenths of the statical breaking weight, and the experiment proceeded with till the number of changes of load reached a million.

The beam had now sustained one million changes of load without any apparent injury; it was then considered necessary to increase the load to 10,486 ℔s, or two-fifths of the breaking weight, when the machinery was again put in motion. With this additional weight the deflections were increased, with a permanent set of ·05 inches from ·23 to ·35, and after sustaining 5175 changes, the beam broke by tension a short distance from the middle. It is satisfactory here to observe that during the whole of the 1,005,175 changes none of the rivets were loosened or broke.

The beam was repaired by replacing the broken angle irons on each side, and putting a patch over the broken plate equal in area to the plate itself. Thus repaired, a weight of three tons was placed on the beam, equivalent to one-fourth of the breaking weight, when the experiments were again continued as before.

At the conclusion of this experiment, the beam having sustained upwards of three million changes of load without any increase of the permanent set, it was assumed that it might have continued to bear alternate changes to any extent with the same tenacity of purpose. It was then concluded to increase the load from one-fourth to one-third of the breaking weight; and having laid on 4 tons, which increased the deflection to ·20 inches, the work was proceeded with in the same order as in the previous experiments.

From these experiments it is evident that wrought iron girders of ordinary construction are not safe when submitted to violent disturbances with a load equivalent to one-third the weight that would break them. They, however, exhibit wonderful tenacity when subjected to the same treatment with one-fourth the load; and assuming that an iron girder bridge will bear with this load 12,000,000 changes without injury, it is clear that it would require 328 years, at the rate of 100 changes per day, before its security was affected. It would, however, be dangerous to risk a load of one-third the breaking weight upon bridges of this description, as, according to the last experiments, the beam broke with 313,000 changes; or a period of eight years, at the same rate as before, would be sufficient to break it. It is more than probable that the beam might have been injured by the previous three million changes to which it had been subjected; and assuming this to be true, it would then follow that the beam was progressing to destruction, and must of necessity at some time, however remote, have terminated in fracture.

The experiments throw considerable light on this very intricate and very important subject. They are probably carried sufficiently far to enable us to state with certainty what is the safe measure of strength; and as much depends upon the quality of the material and the skill with which the girders are put together, it becomes necessary for the public safety that a measure of strength should be established without encumbering the structures with unnecessary weight. On this question it must be borne in mind that every additional ton that is not required beyond the limits of safety, is an evil that operates as a constant quantity tending to produce rupture; and hence follows the necessity of a careful distribution of the material, in order that the tube or girder shall be duly proportioned to the strains it has to bear, and that every part of the structure shall have its due proportion of work to perform.

I have assumed for the sake of illustration, that every description of material, as regards its cohesive properties, follows the same law as that which we have experimented upon, or, in other words, in the ratio of its physical powers of resistance, that is to say, the beam will follow the same law in regard to its ultimate powers of resistance, when operated upon by a corresponding load due to that power. If this be true, we have only to follow the same rule as observed in the experiments, by loading cast iron or wooden beams in the ratio of their cohesive powers of resistance, and their breaking weights respectively. This has not been proved experimentally, but I hope at some future time to have an opportunity of extending the experiments, in order to determine to what extent these views are correct.

The Lords Commissioners of Trade, in the exercise of their functions as conservators of the public safety, have adopted the rule that no railway bridge composed of wrought iron shall exceed with its heaviest rolling load a strain of 5 tons per square inch of section upon any part of the bridge. The formula for this maximum of strain upon the material has been deduced from my own experiments on the model tube of Millwall.

Assuming the top of the girder to be sufficiently rigid to prevent buckling by compression, the formula for the strength of the bottom sections derived from these experiments is—

$$\text{w}=\frac{adc}{l},$$

where the constant $c=80$.

Applying this formula to the beam experimented upon, we have—

a, the area of the bottom $=2{\cdot}4$ inches,
d, the depth of the beam $=16$ inches,
c, the constant deduced from the model tube $=80$,
l, the span or difference between the supports $=240$ inches.

$$\text{Hence—w}=\frac{2{\cdot}4\times16\times80}{240}=12{\cdot}8 \text{ tons},$$

the ultimate strength of the beam.

In order to determine the strain per square inch in these experiments, we find—

$$\text{s}=\frac{lw}{4ad},$$

where s represents the strain per square inch upon the section a, produced by the greatest load w, laid upon the middle of the girder.

It is necessary to observe that in a girder properly proportioned, the greatest strain per square inch will take place upon the bottom section; so that if the strain upon the bottom section of such a girder be within the Government Commissioner's condition of safety, the strain upon the top section will necessarily be within that limit also. In a girder having the cellular structure at its top section, the area of the top section should be very nearly once and a quarter that of the bottom section, or the areas of their sections should be respectively as 5 : 4; and the strain per square inch upon these parts will be respectively inversely as their areas, that is, the strain per square inch upon the top section will be four-fifths of the strain per square inch upon the bottom section. In one of the foregoing experiments, we have—

l, the length of the girder$=240$ inches,
w, the weight laid on the middle $=2{\cdot}96$ tons,
a, the area of the bottom section $=2{\cdot}4$ inches,
d, the depth of the girder $=16$ inches;

$$\text{therefore, s}=\frac{240\times2{\cdot}96}{4\times2{\cdot}4\times16}=4{\cdot}62 \text{ tons},$$

the strain per square inch on the bottom section of the girder.

Applying this formula to the whole series of experiments, we obtain the following summary of results :—

Summary of Results.—1st Series of Experiments.
Beam 20 feet between the supports.

No. of experiment.	DATE.	Weight on middle of beam in tons.	Number of changes of load.	Strain per sq. in. on bottom.	Strain per sq. in. on top.	Deflection in inches.	REMARKS.
1	From March 21st to May 14th, 1860,	2·96	596,790	4·62	2·58	·17	
2	From May 14th to June 26th, 1860,	3·50	403,210	5·46	3·05	·23	
3	From July 25th to July 28th, 1860,	4·68	5,175	7·31	4·08	·35	Broke by tension at a short distance from the centre of the beam.

The number of 1,005,175 changes was attained before fracture, with varying strains upon the bottom flange of 4·62 tons, 5·46 tons, and 7·31 tons per square inch.

Beam repaired.—2d Series of Experiments.

4	August 9th, 1860, .	4·68	158	7·31	4·08	. .	The apparatus was accidentally set in motion.
5	August 11th and 12th,	3·58	25,742	5·59	3·12	·22	
6	From August 13th, 1860, to October 16th, 1861, .	2·96	3,124,100	4·62	2·58	·18	
7	From October 18th, 1861, to January 9th, 1862, . .	4·00	313,000	6·25	3·48	·20	Broke by tension as before, close to the plate riveted over the previous fracture.

Here the number of 3,463,000 changes was attained when fracture ensued.

From the above it is evident that wrought iron girders, when loaded to the extent of a tensile strain of seven tons per square inch, are not safe, if that strain is subjected to alternate changes of taking off the load and laying it on again, provided a certain amount of vibration is produced by that process; and what important to notice is, that from 300,000 to 400,000 changes of this description are sufficient to ensure fracture. It must, however, be borne in mind that the beam from which these conclusions are derived had sustained upwards of 3,000,000 changes with nearly five tons tensile strain on the square inch, and it must be admitted from the experiments thus recorded that five tons per square inch of tensile strain on the bottom of girders, as fixed by the Board of Trade, appears to be an ample standard of strength.

As regards compression, we have only to compare for practical purposes the difference between the resisting powers of the material to tension and compression, and we shall require in a girder without a cellular top from one-third to three-fourths more material to resist compression than to resist tension; and as the strength of wrought iron in a state of compression is to its strength in a state of tension as about 3 to $4\frac{1}{2}$, the area of the top and bottom will be nearly in that proportion, or, in other words, it will require that much more material in the top than the bottom to equalize the two forces.

In the experimental beam the area of the top was considerably in excess of that of the bottom, it having been constructed on data deduced from the experiments on tubes without cells, which required nearly double the area on the top to resist crushing. In the construction of large girders, where thicker plates are used, this proportion no longer exists, as much greater rigidity is obtained in the thicker plates, which causes a closer approximation to equal areas in the top and bottom of the girder; and from this we deduce that from one-third to three-fourths, and in some cases one-third additional area in the top, has been found according to the size of the girder, sufficient to balance the two forces under strain.

The foregoing experiments, however, were instituted to determine the safe measure of strength as respects tension, and it will be seen that in no case during the whole of the experiments was there any appearance of the top yielding to compression.

For the Journal of the Franklin Institute.

The Radial Paddle-Wheel. By JOHN D. VAN BUREN, JR., C. E. U. S. Naval Engineers.

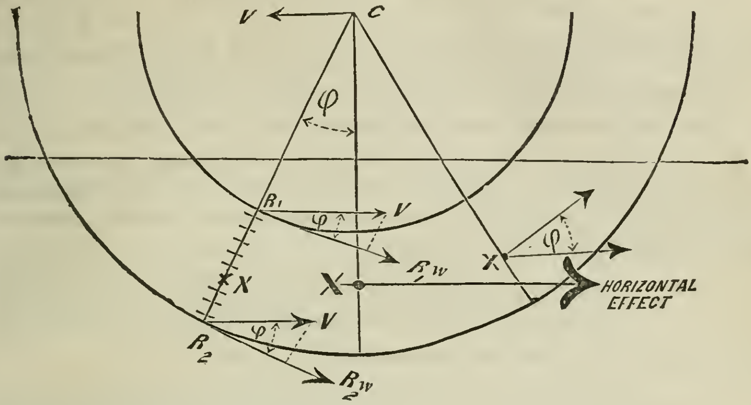
Proposition. To find the centre of dynamic resistence of a radial paddle-wheel propelling a vessel through the water.

Notation.

Let $R_2 = CR_2 =$ distance from centre of shaft to outer line of paddles.
$R_1 = CR_1 =$ “ “ inner “
$x = Cx =$ “ “ centre of normal resistance of paddle $R_1\,R_2$
$w =$ angular velocity of paddle-wheel.
$V =$ actual velocity of vessel through the water.
$\varphi =$ angle made by CR_2 with the vertical.

Let us suppose, that instead of the vessel being propelled through the water while the wheel turns ahead, the water has a current from bow to stern of V. This supposition does not affect the conditions of the problem.

The area of the paddle may be considered made up of indefinately small rectangular areas, the length of each being the length of the paddles, which will be considered equal to 1, since the *length* of the paddle does not influence the distance from the centre of the shaft to the centre of resistance. The breadth or depth of any one of these elementary areas may be represented by the *differential* of its distance from the centre of the shaft, or dr, where r equals that distance. The length being 1, the area is dr.



Now the accepted law of fluid resistance is: The resistance opposed to the motion of any body through a fluid varies with the square of the velocity. In this case the velocity which is effective in producing the resistance to the motion of any one of these elementary areas, dr, through the water, is the difference between the velocity of rotation of this area and that component of the velocity of the current which is normal to the face of the paddle, since the water flows away from the paddle with that component velocity. Therefore for any elementary area dr, we shall have for the velocity effective in producing resistance

$$rw-v\cos\varphi \quad . \quad . \quad . \quad (1)$$

Now calling the resistance per unit of surface, unity, at that point where the velocity effective in producing resistance is 1 (which we are at liberty to do, since the unit of resistance is arbitrary), we have for the resistance of dr at a distance r from c.

$$(rw-v\cos\varphi)^2\,dr \quad . \quad . \quad . \quad (2)$$

The total resistance for the paddle is therefore

$$\int_{R_1}^{R_2}(rw-v\cos\varphi)^2\,dr \quad . \quad . \quad . \quad (3)$$

But the moments of the components summed equals the moment of the resultant; hence

$$x\int_{R_1}^{R_2}(rw-v\cos\varphi)^2\,dr=\int_{R_1}^{R_2}(rw-v\cos\varphi)^2\,rdr \quad . \quad (4)$$

$$\therefore\ x=\frac{\int_{R_1}^{R_2}(rw-v\cos\varphi)^2\,rdr}{\int_{R^1}^{R_2}(rw-v\cos\varphi)^2\,dr} \quad . \quad . \quad . \quad (5)$$

Integrating between limits

$$x=\frac{\frac{1}{4}(R_2{}^4-R_1{}^4)w^2-\frac{2}{3}(R_2{}^3-R_1{}^3)wv\cos\varphi+\frac{1}{2}(R_2{}^2-R_1{}^2)v^2\cos^2\varphi}{\frac{1}{3w}(R_2w-v\cos\phi)^3-\frac{1}{3w}(R_1w-v\cos\varphi)^3}$$

Clearing of fractional co-efficients and expanding terms of denominator,

$$x=\frac{3(R_2{}^4-R_1{}^4)w^2-8(R_2{}^3-R_1{}^3)wv\cos\varphi+6(R_2{}^2-R_1{}^2)v^2\cos^2\varphi.}{4(R_2{}^3-R_1{}^3)w^2-12(R_2{}^2-R_1{}^2)wv\cos\varphi+12(R_2-R_1)v^2\cos^2\varphi} \qquad (6)$$

Let $n=$ number of revolutions of wheel per minute, and $v=mR_2w$ where $m=$ a fraction representing the ratio of the velocity of the vessel to the velocity of rotation of outer circumference of wheel; then $w=2\pi n$. These substituted in (6) give

$$x=\frac{3(R_2{}^4-R_1{}^4)-8(R_2{}^3-R_1{}^3)R_2m\cos\varphi+6(R_2{}^2-R_1{}^2)R_2{}^2m^2\cos^2\varphi}{4(R_2{}^3-R_1{}^3)-12(R_2{}^2-R_1{}^2)R_2m\cos\varphi+12(R_2-R_1)R_2{}^2m^2\cos^2\varphi}.$$

Putting $R_1=pR_2$, there finally results

$$x=R_2.\frac{3(1-p^4)-8(1-p^3)m\cos\varphi+6(1-p^2)m^2\cos^2\varphi}{4(1-p^3)-12(1-p^2)m\cos\varphi+12(1-p)m^2\cos^2\varphi}. \qquad (7)$$

which gives the distance from the centre of the shaft to centre of resistance of the paddle which makes an angle φ with the vertical.

If any of the paddles are not wholly immersed, then, in calculating (7) p must be so altered as to make the distance from the centre of the shaft to the water line of said paddle $R_1'=pR_2$.

If in (7) we make $m=o$, the value of x becomes

$$x=\tfrac{3}{4}R_2.\frac{(1-p^4)}{(1-p^3)} \quad . \quad . \quad . \qquad (8)$$

In this case the vessel does not move, and it answers the case of a vessel moored where there is no current. It will be observed this value of x is entirely independent of ϕ, as it evidently should be, and the centres of resistance of all the paddles will therefore be situated in the same circle. If in addition to this p, or R_1, $=o$, we shall have the wheel immersed to its centre and the breadth of the paddle $=R_2$; and for this case

$$x=\tfrac{3}{4}R_2 \quad . \quad . \quad . \quad . \qquad (9)$$

or, in other words, in a rectangular board, with one of its edges in the surface of the water, and made to rotate about that edge, the centre of resistance is at a distanee of three-fourths of the depth of the board from that edge.

EXAMPLE. Let $R_1=\cdot8\ R_2$ or $p=\cdot8$. Suppose there are five paddles immersed, the upper ones only half submerged. Let $m=\cdot8$, or $v=\cdot8\ R_2\ w_1$, *i. e.* slip $=20$ per cent. Let $\phi_1=\phi_5=60°$, $\phi_2=\phi_4=30°$ $\phi_3=0°$.

Now for the two upper paddles, $p=\cdot9$, we have

$3\,(1-p^4)=3\,(1-\cdot9^4)=1\cdot032$, $8\,(1-p^3)=8\,(1-\cdot9^3)=2\cdot168$,

$6(1-p^2)=6(1-\cdot9^2)=1\cdot14$, $m\cos\phi_1=\cdot8\times\cdot5=\cdot4$, $m^2\cos^2\phi_1\ \cdot64\times\cdot25=\cdot16$

$4(1-p^3)=4(1-\cdot9^3)=1\cdot084$, $12\,(1-p^2)=12\,(1-9^2)=2\cdot28$,

$12(1-p)=12(1-\cdot9)=1\cdot2$

$$\therefore\ {}^*N_1 = N_5 = 3\,(1-p^4) - 8\,(1-p^3)\,m\cos\phi + 6\,(1-p^2)m^2\cos^2\phi = {\cdot}3468$$

$$ {}^*D_1 = D_5 = 4\,(1-p^3) - 12\,(1-p^2)m\cos\phi + 12\,(1-p)m^2\cos\phi = {\cdot}3640$$

To find $N_2 = N_4$, and $D_2 = D_4$,

$$3\,(1-{\cdot}8^4) = 1{\cdot}7712,\ 8\,(1-{\cdot}8^3) = 3{\cdot}9040,\ 6\,(1-{\cdot}8^2) = 2{\cdot}16$$

$$m\cos\varphi_2 = {\cdot}4-\sqrt{3} = {\cdot}6928,\ m^2\cos^2\varphi_2 = {\cdot}48$$

$$4\,(1-{\cdot}8^3) = 1{\cdot}952,\ 12\,(1-{\cdot}8^2) = 4{\cdot}32,\ 12\,(1-{\cdot}8) = 2{\cdot}4$$

$$\therefore\ N_2 = N_4 = {\cdot}1033$$

$$D_2 = D_4 = {\cdot}1111$$

$$(\cos\varphi_3 = 1) \qquad N_3 = {\cdot}0304$$

$$D_3 = {\cdot}0320$$

From (7) we obtain for the distance from centre of shaft to centre of resistance of the different paddles:

Corresponding to ϕ_1, and ϕ_5, half submerged,

$$X = \frac{3468}{3640} R_2 = {\cdot}953\ R_2$$

Corresponding to ϕ_2 and ϕ_4,

$$X = \frac{{\cdot}1033}{1111} R_2 = {\cdot}93\ R_2$$

Corresponding to ϕ_3,

$$X = \frac{304}{320} R_2 = {\cdot}95\ R_2$$

* D Denominator, and N Numerator of (7).

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

Remarkable Plumb-Line Deflection at Cowhythe.

From the London Mechanics' Magazine, October, 1864.

We are enabled to furnish our readers with the following particulars respecting a curious local disturbance of the plumb-line in the neighborhood of Cowhythe, which is now the subject of research, with the view to its being traced on its limit, by a party of the Royal Engineers, under Colonel Sir Henry James, R.E., F.R.S., &c., superintendent of the Ordnance Surveys. Early during the present century, the headland eastward of Portsoy on Cowhythe was visited by an officer of the Royal Engineers with the zenith sector, constructed for the Ordnance Survey of this country by the celebrated Ramsden, and from the observations made with that instrument to determine the latitude of the trigonometrical station there, it was found that the plumb-line, instead of being vertical, was deflected northward of the zenith and southward of the earth's centre, fully nine seconds of angular measure. This extraordinary and unexpected result was viewed with great interest by the scientific world, especially by such as were employed by their respective Governments in connexion with the determination of the figure of the earth; and, by way of verification, a party of the same corps, some sixteen years back, furnished with a new zenith sector, designed by the present Astronomer Royal, and constructed by Troughton and Sims, visited the same spot. More observations, and to a greater number of stars, resulted in confirming the first or earlier determination; and here the matter rested, merely as a subject of occasional wonder to those concerned, till recently the Russian engineers, in prosecution of their national survey, came upon a similar anomaly in the neighborhood of their ancient capital, Moscow. On tracing it to its limit, which they have done in a public-spirited and most creditable manner, they concluded that there is a vacuum, or a comparative vacuum, of a great many square miles in extent, under the earth's surface in that country. To give some idea of the reasoning which leads to so startling a conclusion, the reader may conceive a wide, deep pit with a plummet suspended from its mouth at the earth's surface. The plumb-line will be vertical only when in the centre of the pit (or shaft, as it is called in connexion with mines), because it will there be equally attracted in every direction. If carried round the side of the pit, the line will be so deflected from the vertical as to cause all the lines, if produced upward, to meet in a point above the earth's surface; and such are the phenomena discovered by the geoditical engineers of Russia. The pit, it is true, is closed at its mouth, and no plumb-line can be let down into it, but the spirit-level, being always at right-angles to the plumb-line, discloses the fact as clearly to the mind as the open pit would to the eye. Now, whether the Cowhythe deflection is to be accounted for by a comparative vacuum on the north under the Moray Firth, or by some unknown mass of extraordinary density on the south, or partly by both, is the problem to be solved, and doubtless it will ultimately be solved by the thoroughly trained staff of astronomical observers and computors under their talented chief, Sir Henry James. Their present operations with zenith telescopes, transits, chronometers, theodolites, &c., were commenced at Cowhythe in August, and are now extended, according to the *Banffshire Journal*, southward to the Fourman Hill, near Rothiemay, and Westerfield (formerly known as the Haggs), near Inverkeithny, all in Banffshire where our Highland tourists may see the parties regularly encamped, with their portable observatories and instruments all in working order. The general result can be but briefly stated to be a diminution of the deflection as the observers proceed southwards, but how far it may extend is of course at present unknown.

A Useful Pack-Saddle.

From the London Mechanics' Magazine, November, 1864.

Lieutenant D. M'Mahon, 1st battalion Military Train, has invented and brought into complete working order a most useful species of pack-saddle, adapted to the capacity of horses and mules of various sizes and burdens. By a simple contrivance of turning an inverted screw in the upper part of the frame-work, the saddle is brought to fit the back of any ordinary horse or mule, and is enlarged or rendered suitable to smaller animals as required. The invention has been tested successfully at Woolwich.

For the Journal of the Franklin Institute.

Work and Vis-viva. By DE VOLSON WOOD, Prof. of C. E., University of Michigan.

I have just read the article "On the Elements of Physical Work, &c." by J. W. Nystrom, which is published in the November number of the Journal. I regret to find so many errors in an article which possesses so much merit both in the original manner in which the subject is presented, and in the apt illustrations which accompany his analysis. The geometrical magnitudes used to illustrate his ideas of force, power, and work, struck me very forcibly, and I think they will ever be found serviceable in impressing upon the mind the truths which he has presented.

But I have intimated that there are errors in the article; and it is my present purpose to note them, and not to write a review of the article; and as he comes before us as a truth-seeker, I doubt not he will kindly receive any criticism which may be passed upon it.

If the terms which he uses, as *force*, *work*, *power*, *vis-viva*, &c., are definitions or the names of algebraic expressions, we have only to consider the propriety of their use; but if the terms or phrases involve principles, they must stand the test of analysis.

For instance; if "power," is *defined* to be "the product of the force by the velocity;" or "work," to be "the continued product of the force, velocity, and time;" or vis-viva, to be "the product of mass by the square of the velocity," we have only to consider the propriety of their use; to see if they agree with the terms which have long been used to express the same idea, and if not to see if his terms are better than those used; or if they are new, to see if they are good terms for expressing the ideas intended. Now suppose that we have accepted the definitions which have just been indicated, and that it be asserted that work equals the vis-viva; or $\mathrm{F\,V\,T} = \mathrm{M\,V}^2$. Now this cannot be *assumed* or *defined*, but it must be capable of proof if it be true. I will observe that the equation is true when the force is constant and the body free to move, in which case we have $\mathrm{F\,T} = \mathrm{M\,V}$, also from the law of falling bodies $\mathrm{V} = g\,\mathrm{T}$, which in the preceding gives $\mathrm{F} = \mathrm{M}\,g =$ weight of the body. It must be observed that I admitted the above equality merely for the sake of the argument, and, that I may not be misunderstood, I will state that the first member, $\mathrm{F\,V\,T}$, *does not express the work which the force* F *does upon a body free to move in producing a velocity* V, *in time* T, *but when the body is free to move, as here supposed, it equals one-half the work*, as may be shown hereafter. If it be said, for the sake of the argument, that F is constant and is operating upon a body which offers a constant resistance so that V is also constant, then I say that $\mathrm{F\,V\,T}$ cannot equal $\mathrm{M\,V}^2$; for we have $\mathrm{F\,V\,T} = \mathrm{M\,V}^2$ or $\mathrm{F\,T} = \mathrm{M\,V}$; but in this equation all the quantities are constant except T, hence the equation is not true. If, still further, we admit that $\mathrm{F\,T} = s$, and $\mathrm{V}^2 = 2\,g\,s$, we have by substitution and reduction, $\mathrm{F} = 2\,\mathrm{W}$, which cannot be true. We see then that the equation, $\mathrm{F\,V\,T} = \mathrm{M\,V}^2$, reduces to an absurdity under every hypothesis except the first, and in that it simply gives a true equation without expressing the value of the work. We see then that *it never expresses the true relation between work and vis-viva.*

I have taken more space for this hypothetical case, than I intended to, and yet it will be observed that it is exactly the expression which Mr. Nystrom has given us on pages 326 and 327, vol. xlviii.

But let us notice more specifically some of the statements. The writer says, p. 326, "work appears to be the most confused function in physics," and among other things has been called "vis-viva, living force, power, momentum, &c." I can hardly conceive what class of authors the writer has had access to; for I have yet to find the author —Nystrom excepted—who considers that work means the same as any of the terms above named. It is true that work is known by many terms: for instance, Smeaton called it *mechanical power*; Carnot, moment of activity; Monge and others, *dynamic effect*; M. Navier, *quantity of action*; Poncelet, *quantity of work*; and by most modern writers, simply, *work*. On page 358, he calls $F\,V$, or as he gives it in a few lines after, $M\,V$, *moment of inertia*, while all other writers call it *momentum*; and $\Sigma\, m\, r^2$ is called moment of inertia. I fail to find where "Mosley calls work, 'moment of inertia'" (see p. 359). He says "$S=V\,T$" (see p. 326) which is true when V is constant, and yet in deducing the expression $\frac{M\,V^2}{g}$ (p. 358) he marks $T=\frac{V}{g}$, in which V is variable and increases with the time.

He says, p. 358, that the weight of the moving body at the surface of the earth where $g=32{\cdot}166$, is equal to its mass; whereas, mechanical writers say that the weight equals the mass at the point where $g=1$. Surely if "the difference between force, power, and work, appears not to be generally understood," this is making confusion worse confounded.

I have not made these criticisms in a captious spirit, but rather to help those who read from falling into the same errors.

If Mr. Nystrom has used any expression inadvertently, I hope I have not used it to his disadvantage.

I shall neglect the more agreeable part of my duty, if I do not show the true values and relations of work and vis-viva. I published an article in the November number of the Journal for 1862, and another in the February number for 1864, in which I endeavored to explain their meaning and relation, but as those articles may not be available to the readers of this, I shall make no further reference to them.

Work is overcoming resistance. If the resistance overcome is the inertia of a body, the work is called, *work of inertia*; but the work which has been done upon a body free to move, and which is stored in it, is rarely referred to in this way. It is generally referred to in terms of the vis-viva. The work commonly referred to is that of overcoming physical resistance; and if the resistance be constant and equal F, the work $= F\,S$; if F be variable the work is $\int F\,d\,s$. The expression $F s$, is, I think the primitive formula, not $F V T$ as given on page 327. Now the work done in the space s, is the same whether it be done in one hour, day, or week, it is independent of the time. But if we wish to compare the *efficiency* of machines we must observe the *time* which it takes the different machines to do the same amount of work; then will their efficiencies be inversely as their times of doing the work. It is for this reason that time appears in the English unit of work which is, 33,000 lbs. raised one foot per *minute*. A force may be doing a work of resistance and of inertia at the same time, and the expression $\Sigma P d s$ shows how many pounds feet it has overcome and the expression $\frac{1}{2} M V^2$, how many pounds feet of resistance the moving body is capable of overcoming in being brought to rest. The latter statement requires proof. For this we will suppose that the resistance overcome is constant and equal P; and that it is overcome for a space S. From mechanics we know that the acceleration due to a force, is the force divided by the mass, or $\frac{P}{M}$. We also know that the square of the velocity equals twice the acceleration multiplied by the space, or $V^2 = 2 \frac{P}{M} s$; from which we immediately find $\frac{1}{2} M V^2 = P S$ and as the latter is the work, the former must be also, and hence equals *one-half of the vis-viva.*

This may be proved quite as satisfactorily in a more elementary way. For, the work done may always be made equivalent to a weight W raised to a proper height h. The work of doing this will be $W h$. Now if this weight be permitted to fall freely through the height h, it will acquire a velocity V, and the amount of work stored in the mass must equal $W h$. But from the law of falling bodies we have $h = \frac{V^2}{2g}$ hence, we have $W h = W \frac{V^2}{2g} = \frac{1}{2} M V^2$, as before. I might illustrate these principles by numerous examples, and deduce the expression for vis-viva by different processes, but I trust I have given enough to establish my position. This is all I wish to do at present, but if it seems advisable I may refer to the subject at a future time.

The writer says on p. 359, "that the subject is nowhere properly explained." I confess that much obscurity has hung over the subject principally on account of the brevity of treatment by most authors, but I am pleased to refer your readers to "Morin's Mechanics," as translated by Joseph Bennett, and published by D. Appleton & Co. for a good exposition of the subject. For accuracy, simplicity, and thoroughness, on this subject, it is unequalled by any work within my knowledge. Whewhell in his "Mechanics and Engineering" gives a good exposition of it, and applies the principles of vis-viva to a higher class of problems, than Morin does.

While all standard writers agree upon the terms used in these articles, yet few pretend to define "power." With its present vague meaning it should not be considered a *scientific* term, but if we agree upon the definition given by Mr. Nystrom, it will be as specific as any other term used in science. Morin, in the work above referred to, says, p. 12, "we use the words *power* and *resistance* to denote those forces which favor motion, or those which oppose it;" while the general meaning is, *ability* to do something. We speak of water-power, horse-power, steam-power, power of a lens, power of the wind, mechanical powers, physical power, moral power, and many other abilities, without any idea of the measure of those abilities. It would be a decided gain to physics if it had a specific meaning, and the term force substituted for power in those indefinite expressions.

On the Incrustation of Marine Boilers. By Mr. James R. Napier.

From the London Mechanics' Magazine, November, 1864.

Read before the Institution of Engineers in Scotland, February 17, 1864.

In the Transactions of this Institution, 1859,60, will be found a paper which I wrote, chiefly for the purpose of showing that regenerators, as ordinarily constructed, were much too small for the object intended. But I have there also stated (page 46) that "when these regenerators are made with a sufficient amount of surface, so that abundance of water can be supplied to and discharged from the boilers with little loss of heat, then there will be *no incrustations*," &c. In the last paragraph of the paper I have, with more caution, said, "that this amount of discharge and surface, *it is expected*, will prevent incrustation, and save nine-tenths of the heat at present lost by the ordinary method of blowing off."

The object of the present communication is to show that the practice here recommended leads to results the very opposite of what was expected. Believing, as I then did, in the ordinary theory of blowing off from the boiler before the water became saturated with salts, that an abundant feed and blow-off would prevent the lime depositing, and therefore prevent the incrustations; and being desirous of saving the heat which would otherwise be lost by the great amount of blow-off which I believed to be necessary, I had a regenerator made for the S.S. "Lancefield" with about ten times the surface which it had been customary to give to such apparatus; but the results, as stated at a recent meeting, were so much at variance with my understanding of the ordinary theory, that I think a statement of the facts will help others to a clearer knowledge of the matter.

The vessel then, sailed from Glasgow about noon every Thursday for the Hebrides, lay in one of the lochs there from Saturday evening till Monday morning, and arrived again in Glasgow on Wednesday, to recommence on Thursday a similar voyage. The steam was up or at hand all the voyage; about fifteen stops, of two or three hours each, were made each week, during which time the boiler was supplied with feed by a Giffard's injector, but little or no blow-off.

While steaming, however, the quantity of water continually discharged through the regenerator was so great that the glass hydrometer used for ascertaining the density showed very little difference between the sea and the boiler-water. The boiler was worked in this manner for about four weeks, and then examined; when, instead of being found, as I expected, clean, with little or no scale or deposit, the coating was much thicker, than usual, but soft, very much like newly made mortar, not difficult, before getting dried, to scrape off all accessible places, but which when dry was nearly as difficult of removal as the ordinary compact scale.

During one of the voyages, when I was personally directing the experiment, and had for some time been keeping the greatest amount of feed on the boiler which the engine could supply, I observed the water in the gauge-glass get muddy, but did not then discover the cause. About two years before this I found the same soft limy deposit in the S. S. "Islesman's" boiler, when trying similar experiments on the same station; but as I had disregarded the "Islesman's" experience, and did not then know the experience of others, the "Lancefield's" regenerator was continued, but with lesser quantities of feed and discharge, for about six months, when the tubes of the apparatus giving way, it was discontinued. I was fortunately saved further trouble, and the expense of repairing it, by discovering in the *Annales des Mines* for 1854, an interesting paper by M. Cousté, "On the Incrustations of Boilers." He there shows that the sulphate of lime can be deposited by heat alone, without any evaporation, and that at a temperature of 124°, cent., or two atmospheres of pressure, sea-water in its natural state is very near the point of saturation. As the "Lancefield's" boiler was loaded to nearly 40 ℔s of absolute pressure, and worked generally to about two atmospheres, or 255° Fahr., or about the point of saturation of the lime, it is clear that the greater the amount of sea-water supplied to the boiler, the greater would be the quantity of lime deposited in it. And although there was a constant discharge from the surface by a conical tube, only some of the deposited matter—that which had not attached itself to the boiler—could be so discharged. If this be not the true explanation of the deposit in the "Lancefield's" boiler, of the difficulty of working boilers with sea-water at higher pressures, and of the ordinary experience that boilers are cleaner when worked at a greater density, it will remain for others to explain it.

M. Cousté's experiments, however, appear to me to be conclusive. He suggests a method of getting quit of the lime by filtration at a high temperature. The following extract from his paper shows the conclusions he arrived at from his experiments:—

1. The sulphate of lime is less soluble in hot than in cold, fresh, or sea-water.

For temperatures above 100° cent. the solubility of the sulphate of lime in sea-water diminishes nearly in proportion to the increase of temperature; and, consequently, this solubility diminishes very rapidly with the corresponding increase of pressure.

The following table indicates this solubility for different temperatures, as well as the degrees of concentration at which the saturation of sulphate of lime has place:—

Degrees of the Areometer corresponding to the Saturation.	Temperatures.	Pressures in Atmospheres.	Solubility or Proportion of Sulphate of Lime in 100 of Water at Saturation.
	Degrees.	Atmos.	
12½	103·00	1	0·500
12	103·80		0·477
11	105·15		0·432
10	108·60	1¼	0·395
9	111·00		0·355
8	113·20		0·310
7	115·80	1½	0·267
6	118·50		0·226
5	121·20		0·183
4	124·00	2	0·140
3	127·60		0·097
2	130·00	2½	0·060
1	133·30		0·023

This table expresses that, for example, sea-water boiling at atmospheric pressure, or 103°, will arrive at saturation of sulphate of lime when it will have acquired the concentration of 125° of Baume, and then it will contain 0·500 per cent. of this salt; at 1·25 atmospheres, or 108·6° of temperature, the water will be saturated with sulphate of lime, when the areometer marks 10; it will then contain 0·395 per cent. of sulphate of lime; at two atmospheres, or 124° of temperature sea-water in its natural state, and before it has experienced any concentration, is very near the point where the saturation takes place—for the natural water-marks from 3 to 3·5°,—and in this case the saturation takes place at 4° of concentration.

2. Sulphate of lime becomes wholly insoluble either in sea-water or in soft water at temperatures comprised of 140 and 150° centigrade; and if we expose at these temperatures water containing some of this salt in solution, it is entirely precipitated in the form of little crystals, or of very thin pellicles, according as the salt is more or less abundant in the solution. The sulphate thus precipitated is redissolved after the cooling, but as much more slowly as the temperature at which it is deposited is elevated. That which is deposited at 150° takes many days to re-dissolve.

In the discussion which followed the reading of the paper,

Mr. Elder said he had a good deal to do with the working of boilers at from 30 ℔s to 35 ℔s pressure without surface condensers, and in some cases he had seen very extraordinary deposits. One naturally expected to find most deposit in the section of a boiler where there was most salt and lime; but in a boiler divided into eighteen parts he had found to his surprise, that although in the last section there were two-and-a half times more salt in the water than in that of the first section, yet he could ascertain little difference in the quantity of deposit of lime in any section. He had therefore come to the same conclusion as the President, that the deposit depended upon the temperature of the water, and not upon the quantity of lime in it. The great difficulty they had to contend with in preventing deposit, was that of keeping the circulation in such a state as that the currents would prevent the deposit, for it was found that where there was a current in a boiler the lime did not deposit to any extent. There was certainly no evidence to show that the lime deposited more on account of the presence of a greater quantity of it. The Americans ran with a pressure of 40 ℔s at sea, and they did not appear to suffer much from deposit. They seemed to overcome the deposit of lime by cleaning the boiler whenever they got into port. He was aware of boilers working at 30 ℔s for six or seven years, and the deposit was not greater with that than at lower pressures. He was quite satisfied, with the President, that the lime deposited with pure sea-water, and with sea-water having twice or thrice the usual quantity of salt in it, was the same.

Mr. Lawrie remarked that apparently it was Mr. Napier's opinion that beyond a certain pressure the deposit of sulphate of lime was not aggravated by an increased pressure.

Mr. Elder observed that, though the lime separated from the water, yet it did not necessarily settle down unless it got into eddies. Where the heating surface was, it had no great tendency to deposit. It was found that the deposit occurred in places where there was no great current.

Mr. Lawrie said that they would naturally expect to find it down below the furnace. He asked whether it had been found in practice that there was a greater or less deposit in boilers working at 60 ℔s pressure than at 30 ℔s? He would infer from the discussion that the deposit of sulphate of lime was not greater at the higher pressure.

Mr. Elder had observed boilers working with salt-water for three or four months at 45 ℔s pressure, and he could not say there was much difference between the deposit at that pressure and at 25 ℔s. He believed, however, there was a greater tendency for the lime to separate from the water, but it did not necessarily settle down over the heating surface of the boiler.

Mr. Lawrie said that the gunboats, of which the late Mr. Hughes had great experience, worked at a pressure of 60 ℔s, and no extreme difficulties have been experienced in them.

Professor Thomson suggested that the water might be filtered in a tube 10 or 12 feet long, in which it could be heated up to 150° cent., but this would probably take a good deal of power.

Mr. Elder remarked that nearly every engineer knew of examples of furnace crowns and furnace sides of steam boilers with salt-water tumbling in on account of the deposit of lime or salt on those parts; and it was always considered to be the result of too little blowing off, any such accident being prevented by sufficient blowing off. Were there not other deposits formed at a greater degree of saturation? Suppose they had a quadruple strength of salt in the boiler, was the salt deposited of an injurious kind when it got to a certain density? When did the injurious deposit begin? He believed that when water got to those densities, the lime and the salt formed a crust, and became a non-conductor, and the surface got nearly red hot, and tumbled in. Now, if the lime came out at a temperature of 220°, one would suppose that it would do the same at 230° or 240°. He would have expected that the furnace of the "Lancefield" would have fallen in.

Mr. Jas. R. Napier answered that the sides of most furnaces bulged between the stays, but he did not know the cause of it.

Mr. Lawrie remarked that there seemed to be one very important fact ascertained—that the extensive use of refrigerators could not be attended with the good that was expected from them.

Mr. Jas. R. Napier explained the construction of the "Lancefield's" regenerator, and in reply to inquires, stated that it was about 11 feet high, 20 inches in diameter, and fitted with iron tubes of about $\frac{1}{2}$-inch bore. The tubes gave way at the bottom near the feed inlet. It was very efficient while it lasted. Where there was less water discharged there would be less heat to be saved. Still, the regenerator would always be useful in saving a great portion of the heat that would otherwise be lost.

Mr. Elder observed that the regenerators in the "Shamrock" and "Thistle" wore away rapidly at the ends of the tubes, which were of brass, where the current of water impinged against them, which he believed arose from the mechanical friction caused by the velocity of the water. He would have expected that iron tubes would have gone much more quickly; for in the cases he had mentioned there was no appearance of galvanic action.

Mr. Lawrie said the old refrigerators did not wear away quickly, although the water struck against their brass ends.

Mr. Thomas Russell had seen regenerator tubes worn away both from mechanical action and other causes, such as by rust; whilst he also knew that they worked about ten years in the West India boats, and yet seemed pretty perfect after that, and certainly not worn out; so much so, that when they got new boilers, they repaired their regenerators, and continued to work them for years after that. He did not know whether they were still working them.

Manipulation of Metals.

From the London Mechanics' Magazine, October, 1864.

There are many occasions where a knowledge of some simple alloy or a peculiar solder would save hundreds, yes, thousands of dollars, just as a life may be saved by merely tying a pocket-hankerchief tightly above a bleeding artery. It is only a few years ago that the valve-stem on the engine that runs the *Herald* presses broke in the dead of night, when but half the edition was run off. This was a dilemma, indeed, for a valve-stem is not made in half-an-hour, neither can it be bought at a hardware store like a pound of nails. The engine was injured in a vital part, and unless it was mended the entire edition would be stopped and incalculable loss sustained. Fortunately for the proprietors there was one of the employees present who understood the manipulation of metals, and he informed the by-standers that if they would collect their spare silver he would restore the broken part to a condition of usefulness.

It was done.

The stem was brazed with silver solder, and the engine performed until morning, so that the whole edition was successfully run off. But for the presence of the adept referred to, and his knowledge of this simple process, very great loss would have been incurred.

Some of our readers may be caught in just such a predicament, and we therefore append a formula for a solder which will braze steel. It is as follows: Silver 19 parts; copper 1 part; brass 2 parts; if practicable charcoal dust should be strewed over the melted metal in the crucible.

A good article of yellow brass is extremely desirable for fine work in telescopes and optical instruments generally. A metal that works free and soft under the tool, and is capable of receiving a fair lustre from the burnisher, is always in request. A good yellow brass can be made from the following metals: That denominated "watch-makers brass" is made of one part copper and two parts zinc. German brass is equal parts of copper and zinc; the addition of a little lead makes the metal work easier and less liable to tear under the tool.

In all these mixtures the zinc must be added last, as it is a volatile metal and fuses at a much lower heat than the copper; the melting point of which is 4587°, while that of zinc is only 700°.

Iron and brass must be united by spelter, which is equal parts of brass and zinc. When the joints are cleaned and wired together fine powdered borax is applied to them as a flux. The solder is then dusted on in the form of a powder, or fine filings, and melted in either with a blow-pipe, or by being placed in a charcoal fire. Care must be taken not to melt the brass to be brazed. The solder of course has a much lower fusion point than the metals to be joined, else they would both run at the same time.

A simple method of case-hardening small wrought iron work is to make a mixture of equal parts of pulverized prussiate of potash, saltpetre, and sal ammoniac. The articles must be heated to a dull red, then rolled in this powder, and afterwards plunged into a bath of four ounces of sal ammoniac and two ounces of potash dissolved in a gallon of water.

These simple rules are practical, and will give good results with good workmanship. If the wrought iron is overheated and burned, the unskilful workman must not blame the formula for his failure; or if he put on such a blast as to blow the solder out of the joints, when brazing, and instead of making a joint spoils the job, he must not charge it upon us, but keep a brighter look-out in future. Good rules are useless unless put in force and practised with skill and intelligence.—*Scientific American.*

Storing Explosive Materials.

From the London Artizan, Dec. 1864.

A very interesting operation, which attracted a great number of spectators, has been performed recently at St. Ouen, near Paris. A large floating dock on a new construction—210 feet long, 36 feet wide, and 18 feet high—was launched on the canal. This great iron boat, or floating dock, is intended for a store to hold all description of spirits, oils, or other inflammable liquids. These substances which are so frequently the cause of disastrous fires on land, are now to be secured on water, where they will be comparatively safe from fire. Each of the 100 compartments into which the iron boat is divided is sufficient to contain 250 hectolitres. Ten similar floating warehouses are to be built for the company of the docks of St. Ouen, of which five are already on the stocks. The iron boat was launched sideways into the canal of St. Ouen. After having glided along the slides placed under it, the iron mass, once in the water, moved forward more than forty yards by the force of impulsion. The operation was performed with complete success.

Preservation of Iron in Water.

From the London Artizan, Dec., 1864.

At a sitting of the Academy of Sciences, M. Becquerel read a paper on the preservation of cast iron and iron in fresh water. He had previously shown that when a plate of either material was in contact with a zinc plate not exceeding the hundredth part of the surface of the former, the intensity of the derived electrical currents on the protected metal (iron) would, in sea water, diminish as the distance from the point of contact of the two metals increased; but nevertheless so that the protection afforded by these derived currents would still extend to a considerable distance from the said point of contact. In fresh water there are fewer divided currents on the surface of the metal, a fact which M. Becquerel attributes to the difference of conductability of the two liquids and the degree of chemical action which each exercises on the zinc, since these two circumstances both tend to increase the intensity of the currents. M. Becquerel concludes with saying that a pile of 9837 cannon-balls, 12 centimetres in diameter, may be protected from oxidation under water by surrounding it with zinc bands having an aggregate surface of two square metres.

On the Chemical History and Application of Gun Cotton. By Prof. Abel, F.R.S., Chemist to the War Department.

From the London Chemical News, No. 234.

The history of gun cotton affords an interesting illustration of the facility with which the full development of a discovery may be retarded, if not altogether arrested, for a time, by hasty attempts to apply it to practical purposes before its nature has been sufficiently studied and determined. When Schönbein, in the Autumn of 1846, announced that he had discovered a new explosive compound, which he believed would prove a substitute for gunpowder, the statement attracted general attention, and attempts were made with little delay in different countries to apply the material to purposes for which gunpowder hitherto had been alone used. Schönbein and Böttger (who appear to have discovered gun cotton independently shortly after the former had produced it) lost little time in submitting their discovery to the German Confederation; and a committee was appointed for its investigation, by whom gun cotton was eventually pronounced inapplicable as a substitute for gunpowder.

In this country, gun cotton was experimented with immediately after the method of its preparation was published by Schönbein. Researches were instituted into its nature, preparation, &c., by Porrett and Teschemacher, John Taylor, Gladstone, and others. A few experiments were made on its application as a propelling and mining agent, and the manufacture of the material upon a considerable scale was set on foot by Messrs. Hall, the well-known gunpowder makers at Faversham, a patent having been previously taken out in this country for the production of gun cotton according to Schönbein's process. This factory had, however, not been long in operation before a very disastrous explosion occurred at the works, by which a number of men lost their lives, and which was ascribed to the spontaneous ingnition of the gun cotton, by the jury who endeavored to investigate its cause. From that time the manufacture of gun cotton upon any considerable scale was abandoned in England, and no important contributions to our knowledge of this material were made until, in 1854, Hadow published the results of some valuable investigations, which served to furnish a far more definite knowledge regarding the true constitution and proper method of producing gun cotton than had hitherto existed.

In France, gun cotton was also made the subject of experiments as early as the winter of 1846, and its manufacture was carried on at the Government powder works at Bouchet, near Paris. Some interesting balistic experiments were instituted, under the direction of Piobert, Morin, and other men of eminence, with gun cotton in comparison with different kinds of gunpowder, the results of which indicated that, for producing equal effects to those furnished by a given weight of gun cotton, it was necessary to employ a double quantity of sporting powder, three times the quantity of musket powder, and four times the weight of cannon powder. It was also found that the best results appeared to be obtained by arranging the gun cotton so that it should occupy the same space as the charge of gunpowder required to produce an equal effect; and other data were arrived at, which show that the investigators were being led to work in a direction similar to that afterwards so successfully pursued by Baron Von Lenk in Austria. Unfortunately, however, disastrous explosions occurred at the works at Bouchet, one as early as March, 1847, in a drying chamber, and two, following closely upon each other, in 1848. One of these took place in a magazine near which it was believed that nobody had been for several days; the other occurred also in a magazine where gun cotton was being packed, and on this occasion several lives were lost. These disasters appear to have put an end, until quite recently, to experiments with gun cotton in France.

After the material had been pronounced upon unfavorably by the Committee of the German Confederation, one of its members, Baron von Lenk, continued to devote himself to its study, and with such success, it appears, that a Committee was eventually appointed by the Austrian Government in 1852, to inquire fully into the merits of the material. A sum of money was paid to Schönbein and Böttger in recognition of the value of their discovery, and an experimental manufactory of gun cotton was established at the Castle of Hirtenberg, near Vienna. A particular form of cannon was devised by Baron von Lenk for employment with gun cotton, of which a 12-pounder battery was established. The performances of these guns were considered sufficiently satisfactory to warrant the preparation of four more batteries, which were sent to the Army of Observation in Galicia in 1855, but did not go into active service. It appears that, in consequence of a want of uniformity in the effects of the gun cotton, and of an injurious effect upon the guns, added probably to the prejudice entertained against it by the artillery, the material fell into disfavor, and its application in cannon was for a time abandoned. It was received, however, with much greater favor by the engineers, and was applied with great success to mining and submarine operations. Meanwhile, Baron von Lenk's labors to perfect gun cotton as a material for artillery purposes were unceasing; and at the close of the Italian war the subject of its application was again thoroughly re-opened at the instigation of Count Degenfeld, then Minister of War, who had at an earlier period taken an active interest in Baron von Lenk's investigations. After upwards of one year's experiments, a system of rifled field and mountain guns, to be employed with gun cotton which had been elaborated by von Lenk, was introduced into the Austrian service. Thirty batteries of these guns were equipped, and it was considered as definitely settled that gun cotton would before long be introduced into the service in the place of gunpowder, for artillery purposes. In 1862, however, an explosion occurred at Simmering, near Vienna, where both gunpowder and gun cotton were stored, and this disaster appears to have fortified to such an extent the arguments which were adduced against the employment of gun cotton by its opponents in the artillery service that its use in this direction was again put a stop to for a time. Ultimately a Committee of Investigation was appointed, which consisted in part of eminent scientific men, and which appears, after careful deliberation, to have reported highly in favor of the stability, and important properties as an explosive, of the material,—a report which was supported by the favorable opinion entertained of gun cotton by the Austrian engineers, in whose name Baron von Ebner prepared a very complete and interesting account of the properties and effects of the agent, with particular reference to mining and other engineering operations.

Gun cotton appears, therefore, to have been again restored to favor in Austria, but no official account has reached England up to the present time, with regard to its employment in the recent war operations in that country.

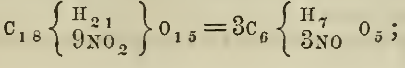
In the Spring of 1862, full details relating to the manufacture and modes of applying gun cotton were communicated by the Austrian Government to that of Her Majesty, and the War Office chemist was at once instructed to institute experiments upon the manufacture of gun cotton, and upon its chemical constitution and stability. In the Autumn of that year General Sabine directed the attention of the British Association to the results obtained with gun cotton in Austria, and a combined Committee of engineers and chemists was appointed to inquire into the subject. At the meeting of the Association in 1863, this Committee presented a report, which was based upon information received partly from General von Lenk, who had been permitted by the Austrian Government to visit this country for the purpose of communicating fully with the British Association on the subject, and partly upon the results already arrived at in the experiments instituted by the lecturer under the direction of the Secretary of State for War. Subsequently a Committee of investigation was appointed by the latter, under the presidency of General Sabine, composed of scientific men connected with the Royal Society and British Association, and of military and naval officers of considerable experience; and this Committee has been entrusted with the full investigation of the properties of gun cotton, as improved by Baron von Lenk, with reference to its application to military, naval, engineering, and industrial purposes.

The chemical constitution of gun cotton, concerning which the opinions of chemists were divided until 1854, has been conclusively established by the researches of Hadow. In the formation of substitution-products by the action of nitric acid upon cotton or cellulose, three atoms of the latter appear to enter together into the chemical change, and the number of atoms of hydrogen re-placed by peroxide of nitrogen in the treble atom of cellulose—

$$C_{18}H_{30}O_{15}=3(C_6H_{10}O_5)$$

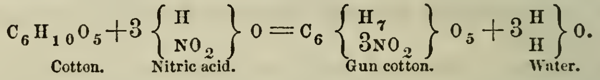
may be nine, eight, seven, or six, according to the degree of concentration of the nitric acid employed.

The highest of these substitution-products is tri-nitro cellulose, pyroxilin, or gun cotton,—



$$C_{18}\left\{\begin{matrix}H_{21}\\9NO_2\end{matrix}\right\}O_{15}=3C_6\left\{\begin{matrix}H_7\\3NO\end{matrix}\right.O_5;$$

this being the substance first produced by Pelouze in an impure condition, in 1838, by the action of very concentrated nitric acid upon paper, or fabrics of cotton, or linen, and afterwards obtained in a purer form by Schönbein, who employed a mixture of concentrated nitric and sulphuric acids for the treatment of cotton-wool; the object of the sulphuric acid being to abstract water of hydration from the nitric acid, and also to prevent the action of the nitric acid from being interfered with by the water which is produced, as the chemical transformation of the cotton into gun cotton proceeds. The formation of trimitro-cellulose is represented by the following equation:—



$$\underset{\text{Cotton.}}{C_6H_{10}O_5} + 3\underset{\text{Nitric acid.}}{\left\{\begin{matrix}H\\NO_2\end{matrix}\right\}O} = \underset{\text{Gun cotton.}}{C_6\left\{\begin{matrix}H_7\\3NO_2\end{matrix}\right\}O_5} + 3\underset{\text{Water.}}{\left.\begin{matrix}H\\H\end{matrix}\right\}O}.$$

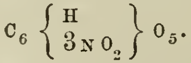
The lowest substitution-product for cotton, of those named above, appears to have the same composition as the substance which Braconnet first obtained in 1832, by dissolving starch in cold concentrated nitric acid, and adding water to the solution, when a white, highly combustible substance is precipitated, to which the name of *Xyloïdin* was given. The substitution-products from cotton, intermediate between the lowest and highest, are soluble in mixtures of ether and alcohol, and furnish by their solution the important material *collodion*, so invaluable in connexion with photography, surgery, experimental electricity, &c.

According to Schönbein's original prescription, the cotton was to be saturated with a mixture of one part of nitric (of sp. gr. 1·5) and three parts of sulphuric acid (sp. gr. 1·85), and allowed to stand for one hour. In operating upon a small scale, the treatment of cotton with the acid for that period is quite sufficient to effect its complete conversion into the most explosive product *pyroxilin*, or *trinitrocellulose*; but when the quantity of cotton treated at one time is considerable, especially if it is not very loose and open, its complete conversion into pyroxilin is not effected with certainty unless it be allowed to remain in the acid for several hours. This accounts in great measure for the want of uniformity observed in the composition of gun cotton and its effects as an explosive, in the earlier experiments instituted; and it is moreover, very possible that the want of stability and, consequently, even some of the accidents which it was considered could only be ascribed to the spontaneous ignition of the material, might have been due to the comparatively unstable character of the lower products of substitution, some of which existed in the imperfectly-prepared gun-cotton.

The system of manufacture of gun cotton elaborated by General von Lenk is founded upon that described by Schönbein; the improvements which the former has adopted all contribute importantly to the production of a thoroughly uniform and pure gun cotton; there is only one step in his process which is certainly not essential, and about the possible utility of which chemical authorities are decidedly at variance with General von Lenk.

The following is an outline of the process of manufacture of gun cotton as practised by Lenk. The cotton, in the form of loose yarn of different sizes, made up into hanks, is purified from certain foreign vegetable substances by treatment for a brief period with a weak solution of potashes, and subsequent washing. It is then suspended in a well ventilated hot air chamber until all moisture has been expelled, when it is transferred to air-tight boxes or jars, and at once removed to the dipping tank, or vessel where its saturation with the mixed acid is effected. The acids of the specific gravity prescribed by Schönbein are very intimately mixed in a suitable apparatus in the proportions originally indicated by that chemist, *i.e.*, three parts by weight of sulphuric acid to one of nitric acid. The mixture is always prepared some time before it is required, in order that it may become perfectly cool. The cotton is immersed in a bath of the mixed acids, one skein at a time, and stirred about for a few minutes, until it has become thoroughly saturated with the acids; it is then transferred to a shelf in this dipping trough, where it is allowed to drain and slightly pressed to remove any large excess of acid, and is afterwards placed in an earthenware jar provided with a tightly-fitting lid, which receives six or eight skeins, weighing from two to four ounces each. The cotton is tightly pressed down in the jar, and if there be not sufficient acid present just to cover the mass, a little more is added: the proportion of acid to be left in contact with the cotton being about ten and a-half pounds to one pound of the latter. The charged jars are set aside for forty-eight hours in a cool place, where, moreover, they are kept surrounded by water to prevent the occurrence of any elevation of temperature and consequent destructive action of the acids upon the gun cotton. The same precaution is also taken with the dipping trough, as considerable heat is generated during the first saturation of the cotton with the acids. At the expiration of forty-eight hours the gun cotton is transferred from the jars to a centrifugal machine, by the aid of which the excess of acid is removed as perfectly as is possible by mechanical means, the gun cotton being afterwards only slightly moist to the touch. The skeins are then immersed singly into water, and moved about briskly, so as to become completely saturated with it as quickly as possible. This result is best accomplished by plunging the skeins under a fall of water, so that they become at once thoroughly drenched. If they are simply thrown into the water and allowed to remain at rest, the heat produced by the union of a portion of the free acids, with a little water would be so great as to establish at once a destructive action upon the gun cotton by the acid present. The washing of the separate skeins is continued until no acidity can be detected in them by the taste; they are then arranged in frames or crates and immersed in a rapid stream of water, where they remain undisturbed for two or three weeks. They are afterwards washed by hand to free them from mechanical impurities derived from the stream, and are immersed for a short time in a dilute boiling solution of potashes. After this treatment, they are returned to the stream, where they again remain for several days. Upon their removal they are once more washed by hand, with soap if necessary; the pure gun cotton then only requires drying by sufficient exposure to air at a temperature of about 27° C. to render it ready for use. A supplimentary process is, however, adopted by General von Lenk, about the possible advantage or use of which his opinion is not shared by others, as already stated. This treatment consists in immersing the air-dried gun cotton in a moderately strong, hot solution of soluble glass (silicate of potassa or soda) for a sufficient period to allow it to become completely impregnated, removing the excess of liquid by means of the centrifugal machine; thoroughly drying the gun cotton thus "silicated" and finally washing it once more for some time until all alkali is abstracted. Lenk considers that by this treatment some silica becomes deposited within the fibers of the gun cotton, which, on the one hand, assists in moderating the rapidity with which the material burns; and on the other hand, exercises (in some not very evident manner) a preservative effect upon the gun cotton, rendering it less prone to undergo even slight changes by keeping. The mineral matter contained in pure gun cotton which has not been submitted to this particular treatment amounts to about one per cent. The proportions found in specimens which have been "silicated" in Austria and in this country, according to Lenk's directions, varies between 1·5 and 2 per cent. It is difficult to understand how the addition of 1 per cent. to the mineral matter, in the form chiefly of silicate of lime and magnesia (the bases being derived from the water used in the final washing) which are deposited upon and between the fibers in a pulverulent form, can influence to any material extent either the rate of combustion or the keeping qualities of the product obtained by Lenk's system of manufacture.

Gun cotton prepared according to the system just described, is exceedingly uniform in composition. The analyses prepared both at Austria and at Waltham Abbey have furnished results corresponding accurately to those required by the formula—



$$C_6 \left\{ \begin{matrix} H \\ 3NO_2 \end{matrix} \right\} O_5.$$

In its ordinary air-dry condition, it contains, very uniformly, about 2 per cent. of moisture—an amount which it absorbs rapidly from the air when it has been dried. The proportion of water existing in the purified air-dried cotton, before conversion, is generally about 6 per cent. When pure gun cotton is exposed to a very moist atmosphere or kept in a damp locality, it will absorb as much as from 6 to 7 per cent.; but if it be then exposed to air of average dryness, it very speedily parts with all but the 2 per cent. of moisture which it contains in its normal condition. It may be preserved in a damp or wet state apparently for an indefinite period without injury; for if afterwards dried by exposure to air, it exhibits no signs of change.

In these respects it possesses important advantages over gunpowder. The normal proportion of hygroscopic moisture in that substance varies three-quarters and one per cent.; but if exposed in any way to the influence of a moist atmosphere, it continues to absorb water until, however firm the grain may have originally been, it becomes quite pasty. It need scarcely be stated that when once gunpowder has become damp it can no longer be restored to a serviceable condition, except by being again submitted to the processes of manufacture, starting almost from the commencement.

Perhaps the most vital considerations bearing upon the possibility of applying gun cotton to important practical purposes, are those which relate to the risk likely to be incurred in its manufacture and preservation, in large quantities. The manufacture of gun cotton is, unquestionably, much safer than that of gunpowder; in fact, there is no possibility of accident until the final drying process is reached, as in all other stages, the material is always wet, and therefore harmless. With the adoption of a proper system of warming and ventilation in the drying chamber, the last operation is certainly not a more dangerous one than that of gunpowder. The question of the safe preservation of gun cotton cannot, as yet, be so easily and satisfactorily disposed of. Specimens of gun cotton exist which were prepared according to Schönbein's directions in 1846, and which have undergone no change whatever; on the other hand, it is well known that gun cotton which was believed to have been perfectly purified, has become extremely acid, and has even undergone so complete a decomposition as to have become converted into oxalic acid and other organic products, when preserved in closed vessels, and especially when exposed continuously or occasionally to light. This susceptibility to chemical change has become particularly observed in samples of gun cotton known to consist chiefly, or to contain some proportion, of the less explosive or lower substitution products (*i. e.*, gun cotton specially prepared for the manufacture of collodion). Hence it is very possible that such instances as are considered to have been well authenticated, of the spontaneous ignition of gun cotton when stored in considerable quantities, or during exposure to very moderate heat, may have arisen, not simply from an imperfect purification of the material, but also from the more or less imperfect conversion of cotton into the most explosive and apparently most stable product.

There is no doubt that the improvements effected in the system of manufacture of gun cotton have been instrumental in rendering it far more stable in character than it was in the early days of its production upon a considerable scale. At the same time, although Gen. von Lenk and its warmest partisans consider that its unchangeability can no longer be disputed, a greater amount of experience, combined with more searching investigation than have hitherto been instituted, upon the possibility of its undergoing change when under the influence of moderate heat, alone or combined with that of moisture, or when preserved under a variety of conditions, are unquestionably indispensable before its claims to perfect permanence can be considered as properly established. It has already been ascertained, by very recent experiments of the lecturer, that gun cotton prepared and purified with the most scrupulous care speedily undergoes some amount of decomposition when exposed to temperatures ranging from 32° to 66° C.;

it remains to be seen whether such decomposition, if once established by exposure of gun cotton to some temperature within the above limit, will cease permanently when the material is removed from the influence of heat, or whether precautions or efficient supplementary processes can be adopted in the manufacture, to counteract the tendency to change exhibited by gun cotton under the above circumstances. These are only some of the points which need patient investigation before it is positively known whether the requisite confidence can be placed in the material, as an agent susceptible of substitution for gunpowder.

It has been ingeniously argued that a slight indication of spontaneous change in gun cotton need give rise to no alarm, because gunpowder is also liable to slight spontaneous change, reference being made to the fact that a very minute proportion of the sulphur in that material has been noticed to undergo oxidation. It need hardly be stated that such a minute change cannot have the slightest effect upon the stability of the mechanical mixture, gunpowder, in which variations as regards purity and proportions of ingredients occur to an extent which render this change of absolute insignificance; whereas, in the case of gun cotton as now manufactured, the development of acid, however minute the proportion, may very possibly give rise to an important disturbance of chemical equilbrium in a compound, the stability of which is based upon the perfect uniformity of its composition; and it may also be at once productive of further change by the tendency which the acid itself has to exert in chemical action upon certain elements of the gun cotton.

The general properties of gun cotton as an explosive agent have long been popularly known to be as follows:—When inflamed or raised to a temperature ranging between 137° and 150° C. it burns with a bright flash and large body of flame, unaccompanied by smoke, and leaves no appreaciable residue. It is far more readily influenced by powerful percussion than gunpowder; the compression of any particular portion of a mass of loose gun-cotton between rigid surfaces will prevent that part from burning when heat is applied. The products of combustion of gun cotton in air redden litmus paper powerfully; they contain a considerable proportion of nitric oxide, and act rapidly and corrosively upon iron and gun-metal. The explosion of gun cotton when in the loose, carded condition—the form in which it was always prepared in the early days of its discovery—resembles that of the fulminates in its violence and instantaneous character. In the open air it may be inflamed when in actual contact with gunpowder without igniting the latter; in a confined space, as in a shell or in the barrel of a gun, the almost instantaneous rapidity of its explosion produces effects which are highly destructive as compared with those of gunpowder while the projectile force exerted by it is comparatively small.

Supply of Water to Cities.

From the Lond. Practical Mechanic's Journal, December, 1864.

M. Grimand de Caux, the French hydraulic engineer, has just read (8th Aug., 1864) a very interesting notice to the Academy of Sciences at Paris, entitled—"Theoretic and Practical indications relative to tho employment, by the Canal of Marseilles, of the waters of the Durance, for domestic use, or for manufactures."

It is well known that Marseilles is supplied with water by the river Durance, which, conducted in artificial channels over limestone mountains and across several valleys—one passed by the celebrated Roque-Faveur aqueduct—for a total distance of about 40 miles, is at last delivered into the numerous fountains of the city; sweeps past every curb-stone in its streets, flushes out its sewers, and at last delivers a copious volume into the old *Toliette*, or inner harbor, and sweeps out to sea the formerly festering mass of putrescent matter that had collected and silted up much of its depth, and often in past times spread pestilence within the city, to which its waters brought trade and wealth. In this latter respect the supply from the Durance has been a matter of unmixed good to Marseilles. The *quality* of the water, however, the quantity of which is so abundant, appears to be by no means so satisfactory; in fact, it appears to be almost unwholesome, and in a very peculiar way unsuited both for manufacturing and for horticultural or agricultural purposes.

The water of the Durance, collected over a vast surface of sub-alpine limestones, is at all times surcharged with an argillaceous mud of excessive fineness. This mud, after its deposit, has been analyzed by M. Pisani. It consists, in 100 parts, of—

Aluminous clay, . . .	56·0
Carbonate of lime, . . .	39·6
Water not expelled at atmospheric temperature, .	4·4
	100

After the most prolonged repose, the whole of this sediment is not deposited, and the water still remains permanently opalescent. Mud deposits sensibly for five days of perfect repose, and after that the opalescence remains unchanged for lengthened periods, if not permanently.

When this water, as delivered by the aqueducts, is employed for watering crops, it has been proved to become a gradual but complete destroyer of fertility. The plants are, in fact, *stifled;* the *stomata* of their root-fibres become plugged up with this impalpable sediment, drawn in along with the water from the soil.

The Durance, in its own natural channel, after it has run as far as Avignon, Orgon, Pertuis, and other towns upon the lower river, is probably not in this state. In virtue of that wonderful power of separation that mere surface contact possesses, the water, while the river is in regimen, is cleared by passing for many miles over its gravely bed.

But amongst the hills, in the neighborhood of St. Paul, where the water has been diverted in order to preserve the necessary head, the slightest rains produce muddiness, and the Marseilles Canal receives the water at once in this state.

When this canal was first projected, there would be in the suburbs of Marseilles about 6000 hectares of land to water. As, according to M. Boussingault, each square metre of land requires in summer (in that locality) from 3 to 4 litres of water per day, there is required for that purpose alone, for the 6000 hectares, or 60,000,000 of square metres, a minimum of 180,000 cubic metres of water. By the aid of settling basins, it is possible to avoid, in part at least, the evil effects of all this mud on vegetation. The upper portion only of the whole depth of water might be drawn off for delivery on the land.

Such a process is applicable to moderate surfaces of cultivated land at least, as, for example, of the gardens around Marseilles, for which, without extravagant cost, settling basins might be provided; but can it be extended to clarify 900,000 cubic metres.

In fact, the municipality of Marseilles has already constructed four great settling basins on the line of the canal; but notwithstanding the repose of the waters in these basins, it enters the pipes of Marseilles still loaded with as much as 33 grammes (or nearly 2000 grains) of mud in the cubic metre. At the present moment (with praiseworthy energy) the city is constructing a fifth settling basin at Réaltort, to contain 3,750,000 cubic metres, and with a water surface of 75 hectares. It is obvious that while basins of this magnitude are exposed to the wind, that sufficient agitation will be propagated from the surface, almost at all times, to prevent a complete deposit of sediment so excessively communicated as this mud of the Durance. In the end, should pellucid water not be thus procured, resort must be had to filtration through sand beds, like those of the double filtering basins of Chelsea. Such filtering beds, which would have to be constructed on the banks of the river, at the point of diversion of the canal, must, on a great scale, be divided into several separate areas for clearing out, &c., and provide for the deposit of about 4 kilogrammes of mud for each cubic metre of content.

However, M. Grimand de Caux continues, the fertilization of the soil is in this case a secondary object. The primary one is to fully and properly supply the city, so that all, rich and poor, shall be provided with good drinking water; until that is accomplished, he rightly says, that in sight of the vast work it has constructed, Marseilles is *not supplied*.

The civic needs are twofold—water for domestic use, and water for manufacturing purposes. M. de Caux calculates that the actual want of Marseilles is, on the whole, 500 cubic metres for 250,000 inhabitants per diem.

Occasional or unusual domestic demands, he thinks, may merge into those for manufacturing uses, and that both may be amply met by a supply of 25,000 cubic metres per diem.

The water capable of being brought in by the aqueduct is greatly beyond these demands. 25,500 cubic metres of the whole should then be deprived of its suspended matter, and the residue of the total delivery after having, at the public fountains, spouted and been divided into *liquid powder* in the air, for the purpose of refreshing it, and promoting the health of the inhabitants, and then circulating past the water kennels, to sweep away their putridity, is to be delivered into the harbor.

With the head of pressure at command in the pipes of distribution the problem of filtration for domestic use appears to M. de Caux to be readily solved. The water will rise far above the top stories of any of the buildings.

He proposes to effect the filtration at the level of the street *in transitu* from the mains to the service pipes.

He fixes the following as primary conditions of filtration :—

The filtering material should be neutral, inert, and incapable of acting injuriously on the water, and acting mechanically only in the removal of the suspended matter. Such are the siliceous gravels and sands of various fineness as set forth by Arago in his report (on Filtration of Paris Water) of 1837. Any substance of organic origin, vegetable or animal, such as sponge, wool, &c., &c., should be excluded as liable to be destroyed by maceration, getting decomposed, and fouling the water passing through them, by microscopic particles of their detritus, or charging it with gases developed in putrefaction.

It is not sufficient for drinking water that it shall have ceased to deposit any sediment, it should be as transparent as crystal, and more especially for the case of a climate such as Marseilles, it should also be fresh and cool.

The water from the main pipes of Marseilles is in each house, whether occupied by one family or in "*apartments*," taken up by a service pipe to the top of the building, and there delivered into a single cistern, and is checked by a self-acting valve or cock ; from,this cistern distributing pipes proceed downwards to each floor, or each set of rooms. The general arrangements being like those adopted for that part of Paris supplied by the fountain of Gaillon, and also of Genoa, where, however, the water, it is said, is delivered by meter.

For all other domestic uses, except drinking, the water is used in its opaline state. For the purpose of rendering it at once pellucid and cool a form of portable domestic filter has been devised by Capt. Aman Vigié, an inhabitant of Marseilles, which is said to act perfectly in the double capacity required of it—namely, that of filtration and refrigeration. It is of the simplest character, though well calculated for its proposed object. Two vessels of pottery, each holding a few gallons, are prepared so that one can be steadily superimposed on the other, without cement or fixture. Into the upper one, which has certain perforations in the bottom, coarse siliceous gravel first, and then two finer qualities of sea sand, all carefully washed, (and sold in that state to the inhabitants,) are filled in and pressed gently down. When the vessel is nearly full, a flat circular plate of pottery, pierced full of small holes, is laid upon the top surface of the sand. This top vessel is glazed inside and out. The lower vessel is made of extremely porous earthenware, like that of the Spanish *alcarazzas*, and has one aperture at one side near the bottom, with an external neck to which a length of vulcanized india rubber tube can be adapted. The length of this tube is a foot or so more than the total height of the two vessels when superimposed. In this state the little apparatus is placed upon a convenient stand, beneath a tap or cock leading from the house cistern, and by preference a position for it in a sharp draught of air is preferred. The cock is turned to the extent that experience shows will supply water as fast as it will filter through. The actual mode of working is to turn on the water by hand when the lower vessel or magazine needs replenishment, and so to turn it off when filled; but it is obvious that the supply might be made automatic easily, and equal to the demand at any moment.

The pellucid water passes into the lower vessel, and therein it becomes cooled, the rapid evaporation from its porous sides producing a powerful refrigeration. The india rubber tube from the adjutage of the lower vessel is brought vertically up the side of the apparatus, and the loose end left lying across the top—in that position, obviously, no water can escape by it. Whenever it is needed to draw off the water, the loose end of the pipe is lowered to the requisite level, and the water flows out into any other vessel held beneath its open extremity.

Thus, without a single close joint or metallic fitment, or valve, or cock, the whole apparatus is complete. It is cheap and simple to the last degree. The aëration of the water is said to proceed in the lower vessel, in virtue of its porous sides, with great vigor, so that drinking water, fully charged with air, and at or below 40° Fah., in the hottest weather, is always commanded.

When the sand, after some weeks use, has begun to get clogged, it is taken out and thrown away, and a fresh charge put in.

Domestic filtering apparatus is common enough in all parts of Europe, but everywhere that we are aware of is constructed on much more expensive and complex designs than this which we have described.

In some, sponge is the filtering medium, the objections to which were long ago pointed out by Arago; in others, porous stones, such as Ransomes; or porous plates, made up of charcoal or coke and baked earth; or woven tissues, &c., form the filtering media. To all these there are objections, in first cost and in use. None of these domestic filters that ever we have seen, combine the advantage of the *alcarazza* principle of cooling in the recipient vessel. This appears to us to be the gaeatest merit of M. Vigié's filter.

We make no doubt but that this domestic apparatus may practically be found to work well in the actual *regime* of life at Marseilles, and, after a time, if indispensable, would, no doubt, be found to do so in England or elsewhere. The filter would come to be understood and worked as easily as moderator lamps, or gas lights, or water closets, and a thousand other more complex things are found to work. But we cannot, nevertheless, but regard the necessity for their adoption at Marseilles as a grave blot upon the hydraulic engineering that has procured for it its supply of water, worthy of all praise as it is in point of copiousness. It points to the fact so well insisted on by M. Grimand de Caux, that too much care cannot be bestowed upon the preliminary inquiries that should be always instituted with the utmost rigidity of science, as to the physical and chemical qualities of the sources proposed to be made available by the hydraulic engineer.

Here is a case in which the beneficent results of one of the most magnificent water projects of modern days—if not of the world—are to a serious extent neutralized by the presence of an insignificant quantity of suspended matter.

The mud, chemically considered, is probably by no means deleterious as regards the calcareous constituent—certainly not so either to animals or plants; yet, in the impalpable division in which it is borne along with this Durance water, it is odious to the eye, if not disagreeable to the palate, and fatal to vegetation.

Without impugning the analysis of M. Pisani, we must entertain a doubt that he looked for silica in the water; and we apprehend that part of the clay or aluminous matter may probably consist in reality of minutely divided silex. If so, the confluent opinion of the physicians of all alpine countries, who have had long experience of the effects of the water of mountain torrents, bearing silica in this impalpable condition, is that it exercises peculiar and highly unwholesome effects upon the animal economy.

It is easy to see to innumerable ways in which opalescent, or slightly muddy water, used for every domestic purpose, with the *exception* of drinking, must yet be productive of disorder, inconvenience, and loss.

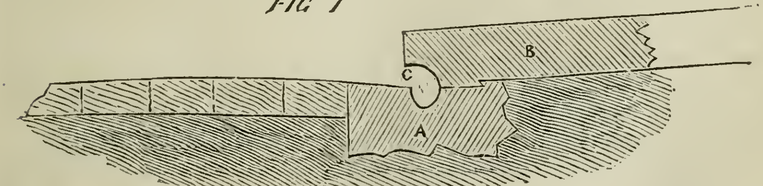
If anything *can* counterbalance such an evil, in the almost tropical climate (for a large part of the year) of Marseilles, it is the magnificent abundance of the supply.

This plentitude of water, delivered at a commanding altitude, is such that both sides of every street in the city runs a rivulet of water, by which the kennels are constantly swept of every impurity.

The water-tables at the curb-edges of very many of the flagged footways, are constructed on a peculiar and excellent plan of great simplicity, which might with advantage be adopted in many places in London and our other great towns.

Fig. 1, is a transverse section of one of those water-tables, the section being, of course, also transverse to the line of street.

FIG 1

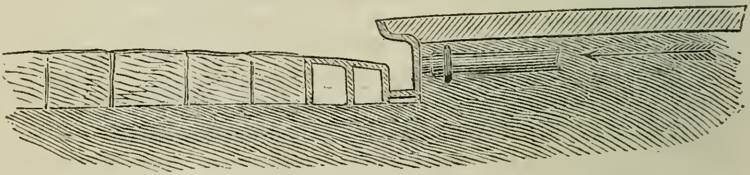


The line of stone blocks, A, form a solid abutment and curb for the pavement, or Macadamising, as the case may be. They are solidly bedded and jointed with asphalt. The hollow grooved channel, which is about 10 to 15 inches in each dimension, is wrought out of the stone, and a rabbet is prepared on the inside part of the top bed, to receive the covering stone, B, which so overbands the former that a wheel or foot, when close to the edge of the footway or kerb, cannot slip into the trough. Every thing finds its way, in heavy rain, into the trough, and from its section, solid matters, such as are found on street surfaces, are swept along, usually without any stoppage, and into the main sewers. When a stoppage does occur, or during the continuance of nearly dry weather, the channels are cleared by sweeping along them a crooked iron instrument, introduced through the continuous slot, C.

The stone employed is Apennine, or sub-apennine limestone, in heavy blocks. The whole construction seems to stand well, and is exposed in several places to very heavy traffic. This construction presents the advantage of leaving the entire breadth of the roadway, from kerb to kerb, at once free for traffic, and free of puddles of nearly stagnant water. It protects the foot passenger from the direful splashing over with mud from the sudden rushing of wheels through the shallow kennell in wet weather, which is so commonly one of the sufferings of the London pedestrian, and, by substituting a form of channel which gives a minimum perimeter and maximum depth, it enables offal to be swept along by the current, that is imperfectly, or not at all, carried along our water kennels.

A form of the same sort of covered water kennel was designed, and, to a small extent, employed by the writer, some years since, constructed in cast iron, as seen in transverse section in fig. 2, and for London streets would be more advantageous than the Marseilles pattern in stone, which involves a rather *higher* kerb than would suit many streets, in the City of London especially. The cast iron channel was cast in one piece, with the exterior curbing, against which the paving of the roadway abutted, and this was formed of hollow cancelated blocks, with roughened upper surfaces, much like those of Messrs. Ransomes, of Ipswich, as laid down some time since in the Poultry, London, and King Street, Westminster. The whole block was bedded in concrete, to the same level as the bottom of the road paving. The inner side of the hollow kennel was provided with faucetts at short intervals, to receive the water from rain-water trunks, or other lateral supplies.

FIG 2



At Marseilles the writer himself remarked that in fine weather the water running in these water kennels is frequently perfectly pellucid at the lower parts of the city, and affords another instance not unworthy of notice of how completely opalescent water is deprived of its suspended matter by long-continued agitation in flow, with large surface contact, and aeration at the same time.—*Ed.*

Substitutes for Indian Ink.

From the London Chemical News, No. 253.

A substance much of the same nature and applicable to the same purposes as Indian ink may be formed in the following manner:—Take of isinglass three ounces: make it into a size by dissolving over the fire in six ounces of soft water. Take then Spanish liquorice one ounce, dissolve it in two ounces of soft water over the fire in another vessel, then grind up on a slab, with a heavy muller one ounce of ivory black with the Spanish liquorice mixture. Then add the same to the isinglass size while hot, and stir well together till thoroughly incorporated. Evaporate away the water, and then cast the remaining composition into a leaden mould slightly oiled, or make it up in any other convenient way. This composition will be found quite as good as the genuine article. The isinglass size mixed with the colors work well with the brush. The liquorice renders it easily dissolvable, on the rubbing up, with water, to which the isinglass alone would be somewhat reluctant; it also prevents it cracking and peeling off from the ground on which it is laid. A good Indian ink may be made from the fine soot from the flame of a lamp or candle received and collected by holding a plate over it. Mix this with the size of parchment, and it will be found to give a good deep color. Burnt rice has been by some considered a principal ingredient in the genuine Indian ink, with the addition of perfumes or other substances not essential to its qualities as an ink.—*British Journal of Photography.*

Coppering Iron Ships.

From the London Artizan, Dec., 1864.

A mode of coppering iron ships, so as to secure freedom from galvanic action, and at the same time attach the sheating firmly, has been invented by Capt. Warren, and is at present in use at the works of Messrs. Brown & Simpson, iron ship-builders, of Dundee. The bottom of the ship to be coppered must be first thoroughly cleaned, and when dry coated all over with Hay's varnish, which must be applied whilst hot. The bottom of the iron ship is then covered with the insultating material used by Capt. Warren, which is a kind of felt of about a fourth of an inch in thickness, and the edges of the layers of this material are lapped over each other for a couple of inches, to insure perfect insulation of the iron. The felt is put on by means of marine glue on it and on the ship's bottom, and pressed hard home—the process presenting little mechanical difficulty. After the ship's bottom has been covered, the outside of the felt or insulator is coated with marine glue upon the parts which are to receive the copper. The copper, which must be previously coated with varnish, is then placed upon the glued felt, the edges of each sheet and layer overlapping the others, the same as in the case of wooden ships. Along these edges nail-holes have been driven for small nails to rivet them together—for though the copper sticks quite strongly enough to the felt, the edges which overlay each other are the better for being thus riveted. The nails for this purpose are very ingeniously contrived, the points of each being split and slightly turned out, so that when they have passed through the two sheets of copper they came in contact with the insulator, and are opened out—thus forming, as Captain Warren says, a perfect clench. The effect of the water wash at the part of the side where the copper leaves off, has also been provided against by Capt. Warren, who carries right round the vessel a batten or beam, on which the upper edge of the copper is fastened, but which is beveled in towards the ship's side at its downward edge, so as to twist the copper violently.

Extracting the juice from Grapes.

From the London Mechanics' Magazine, October, 1864.

We learn from the *Chemical News* that a M. Richter, of Stuttgard, has devised a novel means of extracting the juice from grapes. Instead of pressing them in the ordinary way, he puts them in a drum provided with a suitable strainer, and rotating at the rate of 1000 or 1500 times a minute. The process is said to have the following advantages over the ordinary method:—The time required for the operation is greatly lessened, the whole of the must from one cwt. of grapes being obtained in five minutes; the quantity of juice is increased by five or six per cent.; "stalking" is rendered unnecessary; and the agitated must is so mixed with air that fermentation begins comparatively soon.

Preparation of Blue Ink with Prussian Blue. By M. A. Vogel.

From the London Chemical News, No. 255.

Prussian blue dissolves in oxalic acid, giving a dark blue limpid liquid. This interesting discovery of MM. Stephen and Rasch, patented in England in 1837, is of great interest in tinctorial chemistry, as by its means Prussian blue may be very simply used in the form of a solution. To dissolve commercial Prussian blue in oxalic acid, first mix the blue with concentrated hydrochloric or sulphuric acid, then add an equal weight of water, leave to digest for 48 hours, then carefully extract all the acid by repeated washings. This process being minute and tedious, it is better to employ recently precipitated Prussian blue, which does not need the previous treatment by a concentrated acid.

By the following process the author has always obtained a good solid blue ink with Prussian blue and oxalic acid:—

Dissolve in a matrass, in a large quantity of water, ten grammes of sulphate of protoxide of iron; boil, and then add sufficient nitric acid to sesquioxidize all the iron. Then add a solution of yellow prussiate of potash containing ten grammes of this salt and leave the precipitate to deposit. After decanting the supernatant liquid, throw the deposit on a filter, wash with cold water, and leave it to drain until it can be easily raised from the filter with a knife; then, without further drying, mix it in a porcelian mortar with two grammes of oxalic acid in crystals. Let the reaction continue for an hour, then gradually add 400 cubic centimetres of water. A dark blue solution is thus obtained, in which even after long standing no precipitate is to be found.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, December 15*th*, 1864.

William Sellers, President, in the chair.

John H. Cooper, Recording Secretary, pro tem.

The minutes of the last meeting were read and approved.

The Board of Managers and Standing Committees reported their minutes.

The Special Committees on Weights, Measures, and Coinage of the United States, and on Steam Expansion, reported progress.

The Special Committee on a Uniform System of Screw Threads, &c., presented the following report.

That in the course of their investigations they have become more deeply impressed with the necessity of some acknowledged standard, the varieties of threads in use being much greater than they had supposed possible; in fact the difficulty of obtaining the exact pitch of a thread not a multiple or sub-multiple of the inch measure is sometimes a matter of extreme embarrassment.

Such a state of things must evidently be prejudicial to the best interests of the whole country, a great and unnecessary waste is its certain consequence, for, not only must the various parts of new machinery be adjusted to each other in place of being interchangeable, but no adequate provision can be made for repairs, and a costly variety of screwing apparatus becomes a necessity. It may reasonably be hoped that should a uniformity of practice result from the efforts and investigations now undertaken, the advantages flowing from it will be so manifest as to induce reform in other particulars of scarcely less importance.

Your Committee have held numerous meetings for the purpose of considering the various conditions required in any system which they could recommend for adoption. Strength, durability, with reference to wear from constant use and ease of construction, would seem to be the principal requisites in any general system, for, although in many cases as, for instance, when a square thread is used, the strength of the thread and bolt are both sacrificed for the sake of securing some other advantage, yet all such have been considered as special cases, not affecting the general inquiry. With this in view, your Committee decided that threads having their sides at an angle to each other must necessarily more nearly fulfil the first condition than any other form; but what this angle should be must be governed by a variety of considerations, for it is clear that if the two sides start from the same point at the top, the greater the angle contained between them, the greater will be the strength of the bolt; on the other hand, the greater this angle, supposing the apex of the thread to be over the centre of its base, the greater will be the tendency to burst the nut, and the greater the friction between the nut and the bolt, so that if carried to excess the bolt would be broken by torsional strain rather than by a strain in the direction of its length. If, however, we should make one side of the thread perpendicular to the axis of the bolt, and the other at an angle to the first, we should obtain the greatest amount of strength, together with the least frictional resistance; but we should have a thread only suitable for supporting strains in one direction, and constant care would be requisite to cut the thread in the nut in the proper direction to correspond with the bolt; we have consequently classed this form as exceptional, and decided that the two sides should be at an angle to each other and form equal angles with the base.

The general form of the thread having been determined upon the above considerations, the angle which the sides should bear to each other has been fixed at 60°, not only because this seems to fulfil the conditions of least frictional resistance combined with the greatest strength, but because it is an angle more readily obtained than any other, and it is also in more general use. As this form is in common use almost to the exclusion of any other, your Committee have carefully weighed its advantages and disadvantages before deciding to recommend any modification of it. It cannot be doubted that the sharp thread offers us the simplest form, and, that its general adoption would require no special tools for its construction, but its liability to accident, always great, becomes a serious matter upon large bolts, whilst the small amount of strength at the sharp top is a strong inducement to sacrifice some of it for the sake of better protection to the remainder; when this conclusion is reached, it is at once evident a corresponding space may be filled up in the bottom of the thread, and thus give an increased strength to the bolt, which may compensate for the reduction in strength and wearing surface upon the thread. It is also clear that such a modification, by avoiding the fine points and angles in the tools of construction, will increase their durability; all of which being admitted, the question comes up what form shall be given to the top and bottom of the thread? for it is evident one should be the converse of the other. It being admitted that the sharp thread can be made interchangeable more readily than any other, it is clear that this advantage would not be impaired if we should stop cutting out the space before we had made the thread full or sharp, but to give the same shape at the bottom of the thread would require that a similar quantity should be taken off the point of the cutting tool, thus necessitating the use of some instrument capable of measuring the required amount, but when this is done the thread having a flat top and bottom can be quite as readily formed as if it was sharp. A very slight examination sufficed to satisfy us that in point of construction, the rounded top and bottom presents much greater difficulties, in fact all taps and screws that are chased or cut in a lathe required to be finished or rounded by a second process. As the radius of the curve to form this must vary for every thread, it will be impossible to make one gauge to answer for all sizes and very difficult, in fact impossible, without special tools to shape it correctly for one.

Your Committee are of opinion that the introduction of a uniform system would be greatly facilitated by the adoption of such a form of thread as would enable any intelligent mechanic to construct it without any special tools, or if any are necessary, that they shall be as few and as simple as possible, so that although the round top and bottom presents some advantages when it is perfectly made, as increased strength to the thread and the best form to the cutting tools, yet we have considered that these are more than compensated by ease of construction, the certainty of fit and increased wearing surface offered by the flat top and bottom, and therefore, recommend its adoption. The amount of flat to be taken off should be as small as possible, and only sufficient to protect the thread; for this purpose one-eighth of the pitch would seem to be ample, and this will leave three-fourths of the pitch for bearing surface. The considerations governing the pitch are so various that their discussion has consumed much time.

As in every instance the threads now in use are stronger than their bolts, it became a question whether a finer scale would not be an advantage, it is possible that if the use of the screw thread was confined to wrought iron or brass, such a conclusion might have been reached, but as cast iron enters so largely into all engineering work, it was believed finer threads than those in general use might not be found an improvement, particularly when it was considered that so far as the vertical height of thread and strength of bolt are concerned, the adoption of a flat top and bottom thread was equivalent, to decreasing the pitch of a sharp thread 25 per cent., or what is the same thing, increasing the number of threads per inch 33 per cent. If finer threads were adopted they would require also greater exactitude than at present exists in the machinery of construction, to avoid the liability of overriding, and the wearing surface would be diminished; moreover, we are of opinion that the average practice of the mechanical world would probably be found better adapted to the general want than any proportions founded upon theory alone.

We have taken some pains to ascertain what the proportions in use are, and submit the following, as being in our judgment a fair average, viz:—

Diameter of Bolt,	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8
No. of th'd per in.	20	18	16	14	13	12	11	10	9	8	7	7	6	6	5 1/2	5	5
Diameter of Bolt,	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6
No. of th'd per in.	4 1/2	4 1/2	4	4	3 1/2	3 1/2	3 1/4	3	3	2 7/8	2 3/4	2 5/8	2 1/2	2 1/2	2 3/8	2 3/8	2 1/4

The proportions for bolt-heads and nuts, as given in most of our books of reference, are believed to be larger than necessary, and all are tabulated, necessitating constant reference, a simple formula would be more convenient, and would probably induce a uniform practice, but as most of the sizes in common use are made by machinery and also by hand, it is believed the bolt-head and nut for finished work should be made somewhat smaller than for rough, to avoid the confusion that would ensue if the necessary allowance for dressing should be made upon work intended for finishing.

In conclusion, therefore, your Committee offer the following:—

Resolved, That the Franklin Institute of the State of Pennsylvania, recommend for general adoption by American Engineers, the following forms and proportions for screw threads, bolt-heads, and nuts, viz.

That screw threads shall be formed with straight sides at an angle to each other of 60°, having a flat surface at the top and bottom equal to one-eighth of the pitch. The pitches shall be as follows, viz:—

Diameter of Bolt,	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8
No. of th'd per in.	20	18	16	14	13	12	11	10	9	8	7	7	6	6	5 1/2	5	5
Diameter of Bolt,	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6
No. of th'd per in.	4 1/2	4 1/2	4	4	3 1/2	3 1/2	3 1/4	3	3	2 7/8	2 3/4	2 5/8	2 1/2	2 1/2	2 3/8	2 3/8	2 1/4

The distance between the parallel sides of a bolt-head and nut for a rough bolt shall be equal to one-and-a-half diameters of the bolt, plus one-eighth of an inch. The thickness of the heads for a rough bolt shall be equal to one-half the distance between its parallel sides. The thickness of the nut shall be equal to the diameter of the bolt. The thickness of the head for a finished bolt shall be equal to the thickness of the nut. The distance between the parallel sides of a bolt-head and nut, and the thickness of the nut shall be one-sixteenth of an inch less for finished work than for rough.

Resolved, That a copy of these resolutions be forwarded to the Quarter Master General, Chief of the Bureau of Steam Engineering of the Navy, and the Chiefs of Ordnance for the Army and Navy, and Chiefs of the Engineer and Military R.R. Corps, and the Supt. and M.M. of R.R. Co.'s, requesting them to use their influence to promote the adoption of a uniform system of screw threads, bolt-heads, and nuts, by requiring all builders under any new contracts to conform to the proportions recommended.

Resolved, That a copy of these resolutions be also sent to all Mechanical and Engineering Associations or Institutes, and the principal Machine and Engine Shops in the country, with a request that they will use their influence in the proposed system.

Resolved, That this Committee be now discharged.

WM. B. BEMENT,	*Firm of Bement & Dougherty.*
C. T. PARRY,	*Supt. Baldwin's Locomotive Works.*
J. VAUGHAN MERRICK,	*Firm of Merrick & Sons.*
JOHN H. TOWNE,	*Firm of I. P. Morris, Towne & Co.*
COLEMAN SELLERS,	*Eng. Wm. Sellers & Co.*
B. H. BARTOL,	*Supt. Southwark Foundry.*
EDWARD LONGSTRETH,	*Foreman Baldwin's Locomotive Works.*
JAMES MOORE,	*Firm of Matthews & Moore.*
WM. SELLERS,	*Firm of Wm. Sellers & Co.*
ALGERNON ROBERTS,	*of the Pencoyd Iron Works.*

On motion, it was *Resolved,* That the Report and the Resolutions appended, be printed in the next number of the *Journal,* and that the opinion of persons interested in the subject be invited.

Mr. Caleb P. Jones moved that the adoption of the report be postponed until the next meeting, which was amended by Mr. Thomas Shaw, by adding—"and that the report be printed for the use of the members."

On motion of Mr. J. Vaughan Merrick, seconded by Mr. C. P. Jones, it was ordered that the report, and the resolutions appended, be printed in the next number of the Journal of the Institute, and that the opinions of persons interested in the subject be invited.

Nominations were made for Officers, Managers, and Auditors of the Institute for the ensuing year.

The Board of Managers reported donations to the Library, from

The Royal Astronomical Society, the Royal Society, the Royal Geographical Society, the Commissioners of Patents, the Society of Arts, the Institute of Actuaries, the Statistical Society, the Chemical Society, and the Zoological Society, London; Matthew B. Jackson, Esq. Sheffield, England; the Royal Irish Academy, Dublin, Ireland; T. Oldham, Esq., Superintendent of the Geological Survey of India, Calcutta; the Natural History Society, Montreal; the Literary and Historical Society, Quebec; and the Magnetic Observatory, Toronto, Canada; Hon. Wm. D. Kelley, U. S. Congress, the Smithsonian Institution, Frederick Emmerick, Esq., and Chas. Colné, Esq., Washington, D. C.; F. H. Storer, Cambridge; and Alonzo Tripp, Esq., Roxbury, Massachusetts; Young Men's Institute, Hartford, Connecticut; the Louisville Water Co., Louisville, Kentucky; the Managers of the State Lunatic Asylum, Utica, N. Y.; the Chamber of Commerce, the Mercantile Library Association, the American Institute, John Wiley, Esq., and D. Van Nostrand, Esq., City of New York; the Board of Water Commissioners, Jersey City, N. J.; the Mercantile Library Co., the Common Councils, Pliny E. Chase, Esq., Isaac B. Garrigues, Esq., Wm. Biddle, Esq., Wm. E. Rutter, Esq., Charles E. Smith, Esq., Prof. B. Howard Rand, and Prof. John F. Frazer, Philadelphia.

A paper was read—*On a Practical Photographic*
applications, by J. W. Osbor

ERRATA.

In Mr. Osborne's paper on Photo-lithography, page 57, lines 9 and 14 from the bottom, for "*Photographic*" read "*Photo-lithographic.*"

Page 59, 18th line from the bottom, for "*that*" read "*which.*"

only means
were chiefly devoted to the reproduction of manuscripts and records of importance. The arduous work of the scribe however, proved inadequate to the wants of mankind; and in

fusion that would ensue if the necessary allowance for dressing should be made upon work intended for finishing.

In conclusion, therefore, your Committee offer the following:—

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That screw threads shall be formed with straight sides at an angle to each other of 60°, having a flat surface at the top and bottom equal to one-eighth of the pitch. The pitches shall be as follows, viz:—

Diameter of Bolt,	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$
No. of th'd per in.	20	18	16	14	13	12	11	10	9	8	7	7	6	6	$5\frac{1}{2}$	5	5
Diameter of Bolt,	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
No. of th'd per in.	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3	3	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{1}{4}$

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Wm. Sellers,	*Firm of Wm. Sellers & Co.*
Algernon Roberts,	*of the Pencoyd Iron Works.*

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A paper was read—*On a Practical Photographic Process, and its applications*, by J. W. OSBORNE, Esq., of Australia.

I am happy to have it in my power to respond to your flattering invitation to attend at the present meeting of the Franklin Institute, and shall have much pleasure in bringing under your notice the photographic process which bears my name, and to which I have devoted my attention for several years.

From periods the most remote, the necessity for producing faithful copies of graphic delineations of all kinds, has been keenly felt, and various methods were employed towards that end as civilization progressed. In early times the hand of the copyist was the only means available, and his labors were chiefly devoted to the reproduction of manuscripts and records of importance. The arduous work of the scribe however, proved inadequate to the wants of mankind; and in addition to the literature of that time, there existed also other creations by men of genius, expressive of their highest thoughts and aspirations, which he could not copy; but which were eagerly sought after by the masses of the people as sources of pleasure or instruction. Out of these wants and these desires, grew the noble arts of wood and copper-plate engraving; in connexion with them the printing-press soon followed; and publication with its mighty influence upon the world, became a great reality.

Almost within our own day, Senefelder made his great discovery and worked out his admirable method of printing from stone. To his great talents as an inventor, to his enduring zeal and enthusiasm, and to his single-mindedness as a man, the world is largely indebted. Lithography has not only supplied us with beautiful pictures of undying value, peculiarly its own; but it has also cheapened artistic illustrations for all classes, by the facilities it offers for rapid multiplication in a variety of styles. The cheapness too, with which wood engraving is now produced and the vast improvement in that art during the last thirty years, I believe to be in great part due to the existence of lithography.

Photography, as a method of re-producing the work of the pencil, or the press, next claims our attention. By means of this wonderful discovery, we are enabled to copy and multiply originals of every description with many advantages hitherto unknown. The great mass of the public, is beholden to it for a not inconsiderable acquaintance with the schools of Ancient and Modern Art, and our professional and scientific men no less so for copies of rare documents or drawings, in cases where rapidity, or extreme fidelity, are matters of importance. Photography differs essentially as a means of re-production from the engraving processes to which I have already referred, not only in the details of the peculiar operations which together constitute the process, but fundamentally in its very nature. For, whether we print from wood, or stone, or copper, the engraving upon the block or plate, must in the first instance be produced by the hand and eye of an artist, to effect which his appreciation of form and size is called into requisition, and the power of imitation and execution has to be cultivated. The result by these means approaches excellence in proportion to the care, talents, and experience of the workman, and as he is not infallible, it will always fall short of absolute perfection. Photography on the contrary, embraces within itself, all the necessary resources to accomplish the end in view. The forces which produce the picture, when once called into play, perform their part infallibly, and without the volition of the operator at every step; all he can do is to give them their object, to modify their intensity, to determine when and where they shall commence to act, and for how long a period. As far as outline and form are concerned it is quite possible to produce an absolute fac-simile of any original by this means. The first step in the process (the production of the negative) which corresponds to the execution of the engraved plate or block, is effected by photography in a few minutes, and at an inconsiderable cost, irrespective of the complexity of the original. Its advantages, therefore, as a copying agent can hardly be over-estimated, and they are very generally appreciated and acknowledged. In some respects however, photography as a means of multiplying impressions or proofs stands far below the common printing processes. Its many excellencies are to a certain extent counterbalanced by the fact that positive photographic prints, as at present produced, are not permanent, sooner or later they will fade and lose their value. Their production also is at best a slow process, and therefore costly, and printing operations depend too much upon the state of the weather over which the operator has no control. In one word photography is unexceptionable as a means of producing a faithful transcript of an original, and transcends all other methods; but as a means of multiplying copies, it is unable to compete with the press. This being the case, the thought soon presented itself to experimenters to combine photography with one of the ordinary printing methods, to copy by the one process, and multiply by the other, and accordingly, a great number of inventions have been made, having for their object the production of engraved plates, or raised blocks, or drawings on lithographic stone, by photographic agency which would at the same time prove capable of yielding impressions in the press. Of the nature of these numerous processes, and of their value, and the success they have met with, it is not my intention to speak on the present occasion; my wish is to bring under your notice the particular form of press-photography which I called myself into existence, and which for certain purposes at least, I believed to be unequalled.

My process is designed for the re-production of line drawings and engravings of every description, and the substance upon which I work and from which I print is lithographic stone. The problem I had to solve may be stated as follows:—*From a given original existing as a black and white delineation, to produce by the chemical properties of light a fac-simile upon stone, identical in character with an ordinary lithographic drawing, that has been by the necessary preparation fitted for the printer.*

Before proceeding to describe the way in which this is accomplished it may be well to state for the better elucidation of my subject, that lithographic stone consists of a certain variety of carbonate of lime, which is found in the celebrated Solnhofer quarries, in Bavaria, and is exported to this, and other countries in the form of slabs a few inches thick, and of various sizes. For use, one surface of such a stone is ground smooth and level, and sometimes polished, and upon this the artist executes his work. If a line be drawn upon such a surface with a pen dipped in a peculiar ink, the essential characteristic of which is that it contains fatty matter in solution; or with a crayon made of a mixture of fat, wax, and resinous substances colored with lampblack,—or if we bring in any other way a greasy line upon the stone, and having done so, subject the whole surface to the action of a slightly acidulated gum-water, the face of the stone so prepared will be found to have undergone a change, and to have acquired certain remarkable properties which it did not possess before; in fact we have produced a true lithographic drawing, and from the line above mentioned we can now print impressions in the press. The changes which have taken place by the action of the fatty matter, acid, and gum, upon the carbonate of lime are rather complex, they are for the most part little understood and indifferently explained; the subject is indeed a difficult one, and an exhaustive examination of the phenomena which present themselves in lithography, would form an important and extensive treatise. On the present occasion I must content myself with stating in general terms, that the printing capabilities of a lithographic drawing, after "preparation" or "etching," as it is called, depend upon the adhesive attraction which those parts of the surface constituting the drawing, manifest for greasy matter brought in contact with them, and the repulsion of the same for water. They depend still further upon the converse of this state of things over the rest of the face of the stone, such portions having a strong affinity for water, and when wet, as strong a repulsion for grease. Thus a sort of antagonism is set up, and the surface of the stone is,—if I may be permitted to use the expression,—polarized, as far as its adhesive affinity for grease and water is concerned. This change in physical properties is due to the chemical combinations which have taken place; these, as before stated, are difficult to account for thoroughly, but it will suit our present purpose to bear in mind the leading fact which is this, that a portion of the greasy matter contained in the lithographic ink, enters into combination with the lime of the stone, forming a new substance with it, the boundaries of which are sharply circumscribed. This substance is an insoluble lime soap, and it is neither raised above nor depressed below the face of the stone, and yet constitutes the printing surface, the production of which is the aim of both the lithographic, and photo-lithographic artist.

To obtain a proof on paper from a stone in this condition, the following method is employed. The stone is first evenly damped with a sponge or cloth. The printer's roller charged with ink—a compound of prepared oil and lampblack—is then passed backwards and forwards over the work, whereby it deposits its ink only on the design or drawing; for the moisture on the other parts of the surface hinders its adhesion to them, and causes them to remain perfectly clean. A sheet of paper is next laid upon the stone, which is then drawn through the press; this sheet is then lifted off, and it will be found that the pressure has caused the accumulated ink upon the stone to attach itself to the paper, and produce there the desired impression. These operations are repeated for the next sheet, and so on until the requisite number is printed.

The foregoing very imperfect sketch of lithographic general principles has served at least to define what the end and aim of the photo-lithographer should be. What I have now to describe is the means whereby the hand of man may be dispened with, and its place supplied by photographic manipulations.

Let us suppose that a map has been compiled and drawn with great care, and that it is desired to multiply copies of this original in the lithographic press. The first step in the process is to obtain a negative; for which purpose the map is placed upright upon a plan-board, and the camera opposite to it at such a distance as to give the desired ratio between original and copy. A negative is now taken on glass coated with collodion quite in the usual way, save that the greatest care is observed to avoid distortion of all kinds, and to produce a negative of the highest excellence, success in which depends entirely upon the knowledge, judgment and experience of the operator.

A sheet of plain, positive photographic paper is now coated on one side with a mixture consisting of gelatine, softened and dissolved in water, to which a quantity of bichromate of potash and albumen has been added. The paper, evenly covered with this fluid, is dried in the dark, when it will be found possessed of a smooth glassy surface, and a brilliant yellow color. This surface is still further improved by passing it through the press in contact with a polished plate.

A suitable piece of positive photo-lithographic paper thus manufactured is now to be exposed to the action of the light under the negative of the map already described. This is accomplished in an ordinary pressure-frame, the time required varying from ten or fifteen seconds to several minutes, according to the brightness of the weather; but it is always short compared with that necessary for the production of a picture on paper prepared with chloride of silver. The positive thus obtained presents itself to the eye as a brown drawing upon the clear yellow of the sheet. If the prepared surface of the paper were now moistened with water, and the attempt made to apply printing ink to it, we would find a strong tendency in the albumo-gelatinous surface, to behave towards greasy and watery substances in a manner quite analogous to that already stated as peculiar to a lithographic stone while printing. We would also find that the solvent action of water at any temperature is quite incapable of removing the picture which the sun has imprinted upon it. The light, in fact, has so acted upon the chemical substances brought together upon the surfaces of the paper, that the organic matter is no longer soluble. These are the characteristics of the change due to exposure, which we have to remember.

But the exposed photographic copy of the original is not moistened, or subjected to any solvent action at this stage of the proceedings; it is, on the contrary, covered all over, while dry, with a peculiar lithographic ink known as transfer ink, which is accomplished by running it through the press with its face in contact with a stone which has already received a coating of such ink. After it is separated from the blackened stone it will be found to have brought away with it an evenly distributed film of inky matter forced by the pressure into intimate contact with the unexposed, as well as the exposed portions of the surface. This operation is known as "*blacking*" the positive print; that now to be described is called "*coagulation*," its object being to effect a change of that nature upon the albumen contained in the coating of organic matter. For this purpose moisture and heat are necessary, and both are applied very simply, by letting the blackened photographic copy swim upon the surface of boiling water with its inky side upwards, for it is important not to wet that with hot water. After the lapse of a certain period, determined by the experience of the operator, he proceeds to the next step in the process, that of "*washing off.*" For this purpose the print is laid upon a smooth surface, such as a plate of glass or porcelain, and friction with a wet sponge, or other suitable material, is applied to the black inky coating, under which the photographic image still exists, and to develop which is now the object in view. The operator soon becomes aware that the moisture which percolated through the paper from the back, has exerted a softening or gelatinizing influence upon the gelatine in the sensitive coating; it has caused it to swell, and to let go its hold upon the ink. But this change does not extend to those parts of the coating which were acted on by light; in other words, to those places which were unprotected by the opacity of the negative, they remain intact, uninfluenced by the solvent or moistening effect of the water. Accordingly, the operator finds a fac-simile of the original map gradually develop under his hand as he continues the friction. This process is proceeded with until all traces of ink are removed, save those required to form the picture, which must be clear and distinct in all its details. Abundance of hot water is then poured over it, so as to remove every particle of soluble matter, and it is then finally dried, which completes its preparation. We are now possessed of a photograph in lithographic ink, identical in every respect with the original, not simply upon paper, but upon albuminized paper, a matter of much importance, as will be presently explained. The presence of the albuminous layer under the picture, is the result of the coagulation which took place while the print was swimming on the hot water; after that change no amount of washing could remove it, although the gelatine was not proof against such treatment.

A stone to which a fine smooth surface has been imparted is now slightly warmed, and put in the lithographic press; upon this is placed inverted the positive print, after it has been damped by lying between moist paper, and the whole is then passed repeatedly through the press. On examination the paper will now be found to have attached itself firmly to the stone, so that some force is required to separate the two. When the former is removed it brings with it, its albuminous coating which gives to it while damp a parchment-like appearance; but the ink is gone, it has left the paper for the stone, and on the latter we find a reversed drawing of the map, one, which after it has been properly "prepared" will print as well, as if it had been drawn by hand. The rationale of this method of transfer is easily understood; the greasy ink having a great affinity for the substance of the stone, combines with it to form a lithographic drawing in the strictest sense of the word, and while this is taking place the damp albumen upon the paper, holds the sheet in its proper place so as to prevent a shift of any kind, and enable the pressure to be applied as often as the operator wishes.

I have thus overcome the difficulties of the problem I undertook to solve; I have succeeded in making light do the work of the lithographic artist, as far as copying the original is concerned. The printer can now multiply impressions from such a stone with as much facility as if the drawing upon it was of ordinary, and not photographic origin.

Having now explained the leading operations upon which my photo-lithographic process depends, it may not be out of place to add a few words respecting its history. The immediate cause which prompted me to undertake the invention and elaboration of a process of this kind, was the great necessity which existed in the British colony, Victoria, for some simple, expeditious, and exact method, by which the numerous maps connected with the sale of the public lands might be copied, printed, and published by the Government for the information of the colonists. I was asked to see what could be done in this matter, and the result was the process as I have described it this evening; the invention dating from the 19th of August, 1859. It was instantly adopted by Government, the first map for sale having been produced on the third of September following. Instructions were given to the field surveyors and draftsmen, so as to secure uniformity, and in a wonderfully short time a revolution was effected in the department, which proved very advantageous. Since that time, several thousand different original maps, direct from the hands of the surveyors have been photo-lithographed, whereby a most important saving in time and money has been effected, as well as numberless advantages gained, to which I need not refer in detail. In 1861, the Victorian Government built, at my suggestion, and according to my plan, a large and well appointed Bureau, consisting of many rooms for the more efficient practice of this art, which has been since then in full operation. In the same year the Parliament of Victoria, awarded me by a unanimous vote the sum of £1000, in recognition of my services. I have since my return to Europe resigned my position as chief of this office; but I cannot forbear looking back with pleasure and pride to the time that is past; to its labor and its difficulties, and to its success and triumph also. My process is not the oldest, but it was the first which proved practically valuable, and the Photographic Office in Melbourne, was the first, and for a long time the only establishment where photo-lithography was turned to practical account.

In Berlin, where I recently resided for the purpose of developing my invention in relation to art subjects, my process has been adapted for the production of a large number of illustrations of an important Government work, the Prussian Expedition, to Japan, China, and Siam. They are all of them reproductions of drawings in pen and ink, by the artist who was sent out with the Expedition. The originals are thought to possess much merit, and it would be a great pleasure to me to lay them before the members of the Franklin Institute this evening; that is obviously impossible, but the photo-lithographs which I submit are very faithful fac-similes of them, and will, I doubt not, command your approval. Those which I exhibit—six large plates, and twelve smaller ones, with two maps—are published with the first part of the work.

In conclusion, allow me to draw your attention to a few of the applications which this method of reproduction admits of. For convenience sake, originals susceptible of being copied, may be divided into two great classes. Those which have to be drawn on purpose, or which the advantages offered make it desirable to draw: and those which exist already, and to which this method of exact copying imparts a new interest and importance.

The former class includes several kinds of mechanical drawing, such as maps and plans, architectural designs and drawings of machinery, and in addition to these, pen and ink sketches, involving true artistic talent. Of maps, I have already spoken in the present paper; the application of photo-lithography to them, has advantages too obvious and overwhelming, to require lengthy comment from me; still there are some things which remain to be said, and which I ought not to omit. The original of a new map must be drawn in every case before it can be engraved and published. By applying photo-lithography directly to such an original we save an immense expense, and we accomplish in a *few days*, what, under ordinary circumstances, would occupy *months*. These are advantages which every map publisher will appreciate; but it is only those who are in charge of large governmental departments, on whom the laws of the country, or the exigencies of the times, throw heavy responsibilities; who are daily called upon to supply exact geographical information in their possession, and find their means inadequate; it is only such persons who can fully realize the great benefit which would arise from the employment of a method of reproduction, combining rapidity with absolute fidelity. I could add much more on this theme; I might expatiate upon the gain or loss to the nation, which must often depend upon the publication of a map at the right time; the importance of abundant geographical information to the well-being of the people, both in an educational and material sense, and many other interesting considerations which would naturally flow from the discussion of this part of my topic; but the subject is too large to enter upon at length, and I will content myself with referring to the question which may be raised as to the quality of map-work produced by this means. A moment's reflection will show that this depends entirely upon the way in which the original is drawn; the fac-simile of a good map will be itself a good lithograph, and vice versa. But there is a certain superiority which photo-lithography enjoys to which I have not as yet referred—namely, the power of *reduction*. By this capability of the camera, we are not only enabled to publish originals on various scales; but the draftsman in preparing a map, is at liberty to draw large and rapidly without distress to his sight, and the result is more satisfactory than would be achieved by the greatest labor and care bestowed upon fine and tedious details.

The value which photo-lithography has for the artist who draws with pen and ink for publication, cannot be over-estimated. If he is a man of elevated genius, he will not willingly permit the creations of his mind to appear before the public after they have passed through the hands of a mechanical copyist, which the engraver generally is. This feeling it was, which led many of the great masters, and even artists in our own day to devote themselves to the difficult study of etching: they wished to produce something which could be multiplied in the press, and yet bear the stamp of their own individuality upon it; and they endeavored to accommodate themselves to the use of the etching needle and acid, and all the uncertainties attending them. The artist may now draw upon paper the material to which he is accustomed, and his original he can ultimately retain uninjured; and yet every thought and feeling in it can be reproduced and given to the world with absolute fidelity. This is a boon which artists in Europe have began to avail themselves of, an example which I am convinced their American brethren will not be slow to follow.

The second class of originals suitable for being copied by photo-lithography, embraces those which are already in existence, such as impressions of all kinds taken in the press, together with documents of a historical or personal nature, printed or written by hand. Neglecting the latter on the present occasion, let us consider for a moment the vastness of the store of classical engravings and etchings which, since the introduction of copper-plate printing, have descended to us from the great masters in art.

This is a rich field for the photo-lithographer, one which is inexhaustible and capable of supplying him with an ennobling occupation of undying interest. The production and free circulation amongst the public of works so replete with beauty and lofty sentiment, now difficult of access in consequence of their price and rarity, would be indeed, in my mind, an undertaking of national importance well calculated to advance mankind; but one which I cannot do justice to within the limits of the present paper.

I cannot close this description of my process, and its applications without recording the opinion of a gentleman well qualified to form one; but inclined to a severe judgment from the circumstance that by it, his own work was, and is yet to be published. I refer to the landscape painter, Mr. A. Berg, of Berlin, who accompanied the Japanese Expedition. In writing to me after the appearance of the first part of the Government work which is now before the Society, he says:—

"The President of the Royal Commission, appointed to superintend the publication of the East-Asiatic Travels, has requested me to express to you his grateful acknowledgments of your great services, and disinterested exertions in this work. It gives me particularly great pleasure to be enabled to make this communication to you, and I avail myself of the opportunity to convey to you also my own sincere thanks for your assistance in this work. *You have solved the most difficult problems in this field; problems, the solution of which I myself despaired of, until the successful result was placed before my eyes.* The question whether pen and ink drawings can be multiplied by photo-lithography, and thus made valuable to the artist, is determined by this work."

At the conclusion of his address, Mr. Osborne pointed out and explained the plates exhibited on the walls of the Hall. He also showed reproductions of engravings and wood-cuts, together with map-work of various kinds, chiefly the result of his labors in Australia.

Mr. John Sartain spoke in high terms of the beauty of the plates exhibited to them this evening. They possessed a depth of color and finish which he had rarely, if ever seen equalled by lithography in any form. He had been deeply interested in Mr. Osborne's description of his process, and particularly wished to endorse that part of the lecture having reference to the reproduction of engravings. Even under circumstances the most favorable, when the engraved plate was still to be had, a transfer from it to the stone rarely gave a satisfactory lithograph, and this was more particularly the case with works of high merit. The reason was, that the transfer ink used for this purpose appeared upon the sheet used for transferring, in lines of very appreciable thickness, due to the depth to which those lines were cut in the copper; the ink presented in fact an embossed surface. When such an impression was pulled through upon the stone, the ink became crushed, and the lines of the lithograph lost their purity. Mr. Osborne, made use of a very small quantity of ink without appreciable elevation which could not, and as the specimens before them most satisfactorily demonstrated, did not crush. When the engraved plate was unattainable, and this was the rule and not the exception, Mr. Osborne's process stood quite alone, he had never seen results to compare with it.

Mr. M. P. Simons asked Mr. Osborne to inform them how it happened that he exhibited no photo-lithographs of portraits? He did not see why his process would not produce them and photographs of a similar character as well as line work.

Mr. Osborne explained that the invention was not calculated to render what was known as photographic half tone; other experimenters had devoted themselves to this part of the subject, and it was no doubt a most attractive and important question. The difficulties which attended the production of perfect gradation or half tone, depended upon the fact that in lithographic work the stone was made to represent such tints by giving it a grain, and the graduated shade upon an impression consists not of an even wash; but of an assemblage of little black dots, or markings of varying size, and at different distances from each other. A photographic negative from nature, such as a portrait on the contrary, possessed no such structure, and to produce the former description of drawing by the aid of a negative constituted the real difficulty.

Professor Frazer, said that he had listened to Mr. Osborne's address with the deepest interest. It had often been a source of surprise to him, that more had not been achieved in this direction, particularly when he looked back to what had been accomplished in the early days of the photographic art. He had in his possession a number of views published in Paris, which had been taken as daguerreotypes from natural scenes; they were chiefly architectural subjects, and had been partly etched upon the plate, and partly worked up by hand; but he considered them very interesting exemplifications of what could be done, for notwithstanding the hand work, they still showed their truthful photographic character. Of Mr. Osborne's process, and the work produced by it, he could not speak too highly; they were not from nature, but he was not convinced that the branch of the art thus brought into a perfect and practical form, was of less value and importance than that which aims at the copying of natural objects.

Professor Van der Weyde said that he must differ from Mr. Osborne, as regards the rendering of half tone, or mezzotint effects by photo-lithography; Professor Seely, of New York, had shown him some specimens of the kind from nature, he had forgotten by whom they were; but they demonstrated beyond a doubt the possibility of attaining such effects.

Mr. Osborne, replied that it was far from his intention to imply in any of the remarks he had made, that photo-lithographic half tone was a thing unattained or unattainable; he had only referred to the difficulty, not the impossibility of producing it. On the contrary, he had seen a great deal of work of this sort, some of it very beautiful. A number of experimenters had devoted themselves to its attainment alone, such as Poiterin, Asser, Toovey and others. The specimens referred to by the last speaker, were probably by Cutting and Bradford, of Boston, or by their process. Still, although much had been done, much yet remained to do, for none of the half tone processes were, as far as he, the speaker knew, sufficiently certain and practical to give them a high mercantile value. He believed this would be the case one day, and at no very distant period; but there was a wide difference between the value of the process which produced *work*, and that which furnished specimens only. This subject was a very extensive one, and a comparative enumeration and description of the various processes would alone furnish more than material for a single lecture.

Mr. Coleman Sellers thought Mr. Osborne, had not done his process justice in passing so hastily over the question of the saving effected by it. It was true all processes in which photography played so important a part as it did in that now before them, must be economical. It was easy to see that whether an original was crowded or not, the camera copied it with equal facility; while in the engraver's calculation, the difference in the intricacy, and amount of detail were important items. Reasoning in this way he felt and probably others also, that a great saving must be effected by the application of photo-lithography; but he would be glad if Mr. Osborne could give them some more distinct data to go upon.

Mr. Osborne, replied that the question of economy was partly one of time, and partly one of money; he would endeavor to make some statements which would illustrate the saving that might be effected in both. The lecturer then drew the attention of the meeting to a map produced under official auspices in Melbourne, which had been photo-lithographed and printed for the purpose of establishing how rapidly it could be done. From the receipt of the original to the production of the first impression in the press, the time required was two hours and seven minutes. To lithograph the same map by hand would require a week at least. In the same way two maps had been compared, which he would lay before them; they were both from the same original and on the same scale; but the one was lithographed by hand, the other was photo-lithographed. The former was completed in exactly three days and a half, and cost £4 9*s.* 5*d.*; the latter, with three other maps was photo-lithographed in four hours and forty-eight minutes, and its cost was estimated at six shillings and sixpence. In like manner, on thirty-one maps produced in ten days a saving of upwards of £90 was effected, and the same would have required eighty-nine days to execute in the old way. These facts would be sufficient to show the comparative expense of producing maps by the old and the new methods. The last example quoted was work done at the ordinary rate in the daily routine of office business; in the other two cases every effort was used to ensure rapidity and economy. When pen and ink originals and engravings were copied, great rapidity was of little importance; the object in such cases was to accomplish by photo-lithography, what it was absolutely impossible to accomplish by any other known means, and if it was done within two or three days, the questions of cost might be altogether neglected.

Professor Frazer, said that he thought he expressed the sense of the meeting which he was glad to see so well attended, by proposing a cordial vote of thanks to Mr. Osborne; the members must all feel with him that they had been much interested this evening.

The vote being seconded, and put by the President, was unanimously adopted.

Mr. Osborne returned a few words of thanks and the meeting separated.

A Comparison of some of the Meteorological Phenomena of DECEMBER, 1864, *with those of* DECEMBER, 1863, *and of the same month for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	December, 1864.	December, 1863.	December, for 14 years.
Thermometer—Highest—degree, .	59·00°	60·00°	71·00°
" " date, .	7th.	14th.	2d, 1859.
" Warmest day—Mean,	52·33	54·17	62·80
" " " date,	3d.	13th.	2d, 1859.
" Lowest—degree, .	12·00	15·00	4·50
" " date, .	12th.	23d.	19th, 1856.
" Coldest day—Mean,	19·67	20·67	11·00
" " " date, .	12th.	23d.	18th, 1856.
" Mean daily oscillation,	9·83	13·26	12·17
" " " range, .	7·37	6·54	6·45
" Means at 7 A.M., .	32·92	30·87	31·79
" " 2 P.M., .	38.58	39·13	39·20
" " 9 P.M., .	35·95	34·68	34·69
" " for the month,	35·82	34·89	35·23
Barometer—Highest—Inches, .	30·411 in.	30·495 in.	30·678 in.
" " date, . .	9th.	7th.	18th, 1856.
" Greatest mean daily press.	30·362	30·423	30·611
" " date, . .	9th.	7th.	18th, 1856.
" Lowest—Inches, .	29·071	29·167	28·946
" " date, . .	21st.	14th.	9th, 1855.
" Least mean daily press.,	29·275	29·341	29·175
" " date, . .	21st.	14th.	9th, 1855.
" Mean daily range, .	0·265	0·223	0·216
" Means at 7 A.M., .	29·801	29·999	29·950
" " 2 P.M., .	29·730	29·935	29·908
" " 9 P.M., .	29·782	29·981	29·936
" " for the month, .	29·771	29·972	29·931
Force of Vapor—Greatest—Inches,	0·438 in.	0·486 in.	0·551 in.
" " " date, .	7th.	14th.	2d, 1859.
" " Least—Inches, .	·052	·051	·025
" " " date, .	12th.	11th.	18th, 1856.
" " Means at 7 A.M., .	·152	·142	·143
" " " 2 P.M., .	·161	·156	·169
" " " 9 P.M., .	·169	·145	·156
" " " for the month,	·161	·148	·156
Relative Humidity—Greatest—per ct.,	92·0 per c.	96 per ct.	100 per c
" " " date,	2d.	14th.	often.
" " Least—per ct.,	26·0	35·0	23·0
" " " date, .	1st.	24th.	15th, 1861.
" " Means at 7 A.M.,	77·3	74·1	77·2
" " " 2 P.M.,	64·8	59·8	65·3
" " " 9 P.M.,	74·8	68·5	75·0
" " "for the month	72·3	67·5	72·5
Clouds—Number of clear days,* .	3	10	8·6
" " cloudy days, ·	28	21	22·4
" Means of sky cov'd at 7 A.M.,	73·2 per c.	56·1 per c.	64·0 per c.
" " " " 2 P.M.,	77·7	56·8	63·9
" " " " 9 P.M.,	77·7	47·4	48·4
" " " for the month,	76·2	53·4	58·8
Rain and melted Snow—Amount,	4·754 in.	4·871 in.	3·711 in.
No. days on which Rain or Snow fell,	19.	10·	10·6
Prevailing Winds—Times in 1000	S72° 54′W·158	N72° 0′W ·243	N62° 15′W·271

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* Sky one-third or less covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the year 1864, *with those of* 1863, *and of the last* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	1864.	1863.	13 years.
Thermometer—Highest—degree, .	96·00°	95·00°	100·50°
“ “ date, .	June 26th.	Aug. 10th.	July 21st '54
“ Warmest day—Mean,	89·67	88·50	91·30
“ “ “ date,	June 26th.	Aug. 10th.	July 21st '54
“ Lowest—degree, .	4·00	5·00	—5·50
“ “ date, . .	Feb. 17th.	Feb. 5th.	Jan. 23d '57
“ Coldest day—Mean,	7·00	11·17	—1·00
“ “ “ date, .	Feb. 17th.	Feb. 4th.	Jan. 9th '56
“ Mean daily oscillation,	13·79	14·63	15·04
“ “ “ range, .	5·27	5·39	5·53
“ Means at 7 A. M., .	50·40	49·98	49·77
“ “ 2 P. M., .	59·66	59·21	59·88
“ “ 9 P. M., .	53·75	53·21	53·19
“ “ for the year,	54·60	54·13	54·28
Barometer—Highest—Inches, .	30·411 in.	30·671 in.	30·704 in.
“ “ date, . .	Dec. 9th.	Feb. 4th.	Jan. 28th '53
“ Greatest mean daily press.	30·362	30·553	30·611
“ “ date, . .	Dec. 9th.	Jan. 18th.	Dec. 18th '56
“ Lowest—Inches, . .	29·071	29·127	28·884
“ “ date, . .	Dec. 21st.	Jan. 16th.	Ap. 21st '52
“ Least mean daily press.,	29·150	29·298	28·959
“ “ date, . .	Nov. 4th.	Jan. 16th.	Ap. 21st '52
“ Mean daily range, .	0·152	0·157	0·156
“ Means at 7 A. M., .	29·772	29·879	29·880
“ “ 2 P. M., .	29·730	29·835	29·840
“ “ 9 P. M., .	29·775	29·877	29·867
“ “ for the year,	29·759	29·864	29·862
Force of Vapor—Greatest—Inches,	0·895 in.	0·980 in.	1·059 in.
“ “ “ date, .	Aug. 2d.	Aug. 10th.	June 30th '55
“ “ Least—Inches, .	·022	·027	·013
“ “ “ date, .	Feb. 17th.	Feb. 4th.	Feb. 6th '55
“ “ Means at 7 A. M.,	·314	·316	·323
“ “ “ 2 P. M.,	·321	·322	·338
“ “ “ 9 P. M.,	·338	·332	·344
“ “ “ for the year,	·324	·323	·335
Relative Humidity—Greatest—per ct.,	100 per ct.	100 per ct.	100 per ct.
“ “ “ date,	Jan. 18th.	Jan. 21st.	often.
“ “ Least—per ct.,	18·0	15·0	13·0
“ “ “ date, .	Mar. 9, Ap. 7	April 26th.	Ap. 13th. '52
“ “ Means at 7 A. M.,	72·0	74·5	75·7
“ “ “ 2 P. M.,	53·9	56·7	57·1
“ “ “ 9 P. M.,	68·9	70·5	72·0
“ “ “ for year,	64·9	67·2	68·3
Clouds—Number of clear days,* .	94	93	109
“ “ cloudy days, .	272	272	256
“ Means of sky cov'd at 7 A. M.	61·8 per c.	63·4 per c.	60·0 per c.
“ “ “ “ 2 P. M.	66·6	63·9	60·8
“ “ “ “ 9 P. M.	52·4	49·9	45·8
“ “ “ for the year,	60·2	59·1	55·5
Rain and melted Snow—Amount,	46·730 in.	49·642	45·436 in.
No. of days on which Rain or Snow fell,	128·	143·	128·
Prevailing Winds—Times in 1000,	S82°22′W·220	N65°19′W·149	N75°53′W·205

*Sky, one-third or less covered at the hours of observation.

A General Abstract of the Meteorological Observations made at Philadelphia during the year 1864.—By Prof. JAMES A. KIRKPATRICK.

Latitude 39° 57½′ N. Longitude, 75° 10½′ W. from Greenwich. Height of Barometer fount, sixty feet above mean tide in the Delaware River.

1864.	Thermometer.									Barometer.								Dew Point.			
MONTHS.			Range.			Means.						Range.		Means.				Means.			
	Maximum.	Minimum.	Monthly.	Mean daily.	Mean daily oscillation.	7 A. M.	2 P. M.	9 P. M.	Average	Highest.	Lowest.	Monthly.	Mean daily.	7 A. M.	2 P. M.	9 P. M.	Average.	7 A. M.	2 P. M.	9 P. M.	Average.
	°	°	°	°	°	°	°	°	°	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	°	°	°	°
January,	65	7	58	5·85	13·74	29·89	37·48	32·24	33·20	30·271	29·257	1·014	·206	29·886	29·847	29·913	29·882	21·19	23·13	23·25	22·52
February,	57	4	53	7·18	15·29	30·55	40·57	34·74	35·29	30·375	29·284	1·091	·182	29·792	29·742	29·796	29·777	21·89	20·56	23·44	21·96
March,	59	20	39	5·11	13·55	34·35	45·07	39·03	39·48	30·131	29·184	·947	·176	29·723	29·656	29·699	29·693	25·93	25·57	28·15	26·55
April,	75	32	43	5·27	15·40	44·90	55·58	48·45	49·64	30·048	29·310	·738	·122	29·730	29·699	29·755	29·728	35·74	36·83	37·80	36·79
May,	86	41	45	5·03	16·61	62·53	73·55	65·15	67·01	30·000	29·379	·621	·108	29·663	29·627	29·665	29·652	53·40	54·78	55·92	54·69
June,	96	51	45	5·69	17·42	67·33	78·23	70·03	71·86	30·087	29·296	·791	·127	29·812	29·777	29·805	29·798	55·25	56·22	58·27	56·58
July,	94	60	34	3·81	15·73	72·39	83·48	76·97	77·61	30·066	29·518	·548	·114	29·784	29·747	29·783	29·771	60·58	59·92	63·24	61·25
August,	96	61	35	2·73	11·71	75·26	84·19	78·43	79·29	29·938	29·437	·501	·082	29·726	29·694	29·726	29·715	65·14	64·90	67·08	65·71
September,	81	51	30	4·82	12·30	63·22	70·78	66·32	66·77	30·117	29·450	·667	·103	29·786	29·760	29·795	29·780	54·80	54·72	55·78	55·10
October,	75	36	39	4·56	13·16	50·11	59·37	53·18	54·22	30·022	29·218	·804	·129	29·715	29·674	29·726	29·705	41·39	41·72	43·53	42·22
November,	69	25	44	5·84	10·80	41·30	49·22	44·57	45·03	30·347	29·080	1·267	·208	29·848	29·803	29·849	29·833	34·23	35·38	35·76	35·12
December,	59	12	47	7·37	9·83	32·92	38·58	35·95	35·82	30·411	29·071	1·340	·265	29·801	29·730	29·782	29·771	26·33	27·15	28·58	27·35
Annual means,	96	4	92	5·27	13·79	50·40	59·66	53·75	54·60	30·411	29·071	1·340	·152	29·772	29·730	29·775	29·759	41·32	41·74	43·40	42·15
Winter,	65	4	61	6·52	14·10	30·44	39·06	33·89	34·46	30·495	29·167	1·328	·204	29·892	29·841	29·897	29·877	22·22	23·14	23·93	23·10
Spring,	86	20	66	5·14	15·19	47·26	58·00	50·88	52·05	30·131	29·184	·947	·135	29·705	29·661	29·706	29·691	38·36	39·06	40·62	39·35
Summer,	96	51	45	4·08	14·95	71·66	81·97	75·14	76·26	30·087	29·296	·791	·108	29·774	29·739	29·771	29·761	60·32	60·35	62·86	61·18
Autumn,	81	25	56	5·07	12·09	51·54	59·79	54·69	55·34	30·347	29·080	1·267	·147	29·783	29·746	29·790	29·773	43·47	43·94	45·02	44·14
Means for 13 years,	100½	—5½	106	5·53	15·04	49·77	59·88	53·19	54·28	30·704	28·884	1·820	·156	29·880	29·840	29·867	29·862		43·27		

Table (*Continued*).—*A General Abstract of the Meteorological Observations made at Philadelphia during the year* 1864.

1864.	Relative Humidity.							Force of Vapor.							Clouds. Sky Covered.				Rain or melted snow		Winds.	
				Means.							Means.				Means.							
Months.	Maximum.	Minimum.	Range.	7 A. M.	2 P. M.	9 P. M.	Average.	Maximum.	Minimum.	Range.	7 A. M.	2 P. M.	9 P. M.	Average.	7 A. M.	2 P. M.	9 P. M.	Average.	Amount.	No. of days it fell.	Monthly resultant.	No. of times in 1000.
	Pr. ct.	Pr. ct.	Pr. ct.	Per cent.	Per cent.	Per cent	Per cent.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Inch.	Days	Direct'n from	
January,	100	34	66	73·1	57·8	69·5	66·8	·396	·025	·371	·133	·137	·140	·137	60·0	52·9	41·6	51·5	1·878	10	N 78° 41′ W	319
February,	90	20	70	70·1	46·6	63·8	60·2	·262	·022	·240	·132	·124	·139	·132	50·7	63·1	47·6	53·8	0·697	5	S 80 41 W	379
March,	95	18	77	71·5	50·4	65·8	62·6	·361	·064	·297	·146	·149	·160	·152	61·0	63·5	50·3	58·3	5·243	10	N 46 7 W	221
April,	92	18	74	71·0	52·2	67·8	63·7	·495	·096	·399	·219	·232	·236	·229	62·7	73·3	69·0	68·3	4·478	14	N 13 23 W	133
May,	97	32	65	73·2	54·5	73·6	67·1	·714	·202	·512	·423	·452	·461	·445	62·9	69·0	58·4	63·4	9·042	12	S 22 23 W	105
June,	89	24	65	65·9	48·4	67·1	60·4	·850	·221	·629	·454	·475	·503	·477	48·7	54·7	46·0	49·8	2·246	7	S 73 30 W	343
July,	97	27	70	67·2	46·6	63·2	59·0	·860	·255	·605	·540	·537	·592	·556	62·9	58·7	35·8	52·4	3·742	8	S 75 5 W	263
August,	90	38	52	71·3	53·3	68·7	64·4	·895	·307	·588	·633	·630	·673	·645	70·6	77·4	58·4	68·8	1·539	9	S 42 39 W	298
September,	97	39	58	74·5	57·8	69·5	67·3	·741	·258	·483	·442	·439	·454	·445	62·3	70·7	47·7	60·2	7·317	13	S 69 25 W	244
October,	91	36	55	72·7	53·9	70·6	65·8	·703	·138	·565	·278	·285	·300	·288	54·8	64·8	34·5	51·4	1·729	8	N 82 34 W	276
November,	94	30	64	76·2	60·9	72·2	69·8	·548	·082	·466	·218	·227	·227	·224	72·7	73·0	59·7	68·5	4·065	13	S 83 40 W	269
December,	92	26	66	77·3	64·8	74·8	72·3	·438	·052	·386	·152	·161	·169	·161	73·2	77·7	77·7	76·2	4·754	19	S 72 54 W	158
Annual means,	100	18	82	72·0	53·9	68·9	64·9	·895	·022	·873	·314	·321	·338	·324	61·8	66·6	52·4	60·2	46·730	128	S 82 22 W	220
Winter,	100	20	80	72·4	54·7	67·3	64·8	·486	·022	·464	·136	·139	·141	·139	55·6	57·6	45·5	52·9	7·446	25	N 85 5 W	306
Spring,	97	18	79	71·9	52·4	69·1	64·5	·714	·064	·650	·263	·278	·286	·276	62·2	68·6	59·2	63·3	18·763	36	N 52 39 W	96
Summer,	97	24	73	68·1	49·4	66·3	61·3	·895	·221	·674	·542	·547	·589	·559	60·7	63·6	46·7	57·0	7·527	24	S 63 49 W	290
Autumn,	97	30	67	74·5	57·5	70·8	67·6	·741	·082	·659	·313	·317	·327	·319	63·3	69·5	47·3	60·0	13·111	34	S 83 48 W	253
Means for 13 years,	100	13	87	75·7	57·1	72·0	68·3	1·059	·013	1·046	·323	·338	·344	·335	60·0	60·8	45·8	55·5	45·436	128	N 75 53 W	205

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PROMOTION OF THE MECHANIC ARTS.

FEBRUARY, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Leveling and Surveying by means of a Visual Angle and Rod.

Treated by S. W. Robinson, C. E.

This method of leveling and surveying, I think has not, as yet, come into so general use as its merits demand. Where extreme accuracy is not required, it is a rapid means of performing many field operations, which, as now usually done, require both the leveling and transit instruments.

To form a visual angle with which to make readings upon the rod with suitable exactness, a telescope, provided with a reticule of spider's threads is required. For leveling purposes we must have a vertical graduated limb upon the axis of the telescope; and for plotting the work, readings from a horizontal limb. The theodolite then is the instrument best adapted to the purpose.

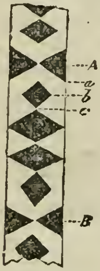
The visual angle may be variable,—formed between two spider-threads in the focus of the instrument, one or both of which is moveable by a micrometer head,—or they may be stationary forming a constant angle. The latter is probably preferable, in consequence of the liability of the micrometer to get out of adjustment; and of a greater amount of computation required to reduce the observations.

The constant visual angle should usually be within the limits of 25 to 35 minutes of arc.

To determine a distance, this angle being known, let the instrument be centered over one of the two points between which the distance is to be found, and the rod provided with two targets, over the other; and both targets adjusted to appear to the observer to be exactly upon the two horizontal threads. When the distance between the two targets is measured, we have the base of an isoceles triangle in which all the angles become known.

But a much more convenient arrangement than the rod and targets, is a flat surface of three or four inches width and the required length, painted in such a manner that the distance can be read to a foot by the observer himself. By the French this is called a *stadia*. One of the best forms for painting the stadia is represented in Fig. 1, A B corresponding to a distance of 100 feet, A *a*, *a b*, *b c*, &c. to distances of 10 feet. Closer readings come from estimation. In this, after a little practice there is never any trouble in getting the nearest foot. Narrower spaces become indistinct at too short distances; but a stadia like Fig. 1, is easily read to the nearest foot with an orinary Würdemann theodolite at a distance of 1500 feet. This distance with a vertical angle of 25 or 30 degrees closely read, will determine the height of several hundred feet to the fraction of a foot.

FIG. 1.



A sufficient number of courses run over an irregular surface of ground, an azimuth carried* and readings noted:—these points and their heights plotted upon paper will give at once the topography, and this too, probably by the *most rapid method*, except perhaps the plane table in the open field. Preliminary lines can be expeditiously run; and leveling done for profiles, &c., while all the reading and measuring is under the direct control of the engineer himself.

The error of the stadia measurement has been found to be about one foot in 800 or 1000; one foot in 1000, being that usually allowed in chaining. To my knowledge courses have been run from one to six miles, over heights of 150 to 200 feet, in which the final error in height ranged from 0 to 1·5 feet with no more than ordinary care.

The stadia was used for getting the topography of some densely wooded timber land in the summer of 1863. The courses were so run as to connect points of triangulation from one to four miles apart. The distances from point to point along the courses, ranged from 100 to 500 ft. The latitudes and departures were subsequently computed with the object of finding the error of stadia measurement. The results obtained were about 1 foot in 800, 1000, and 1100 feet.

In the month of October last, a base of 1347·3 feet was measured with the stadia giving 1346 ft. Also a base of 1798·9 ft., by two persons; giving independently, 1800 ft. and 1798 ft.

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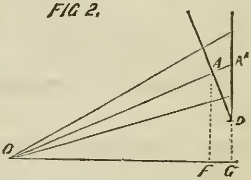
* That is,—keeping the 0° and 180° points of the horizontal limb constantly in a line parallel to that of their first position; which is done by keeping the vernier and limb, or upper movement clamped after the fore-sight is taken till after the instrument is carried forward and a back-sight is taken upon this same stake, and the lower movement clamped. Then the upper movement is to be unclamped and the telescope turned for taking the next fore-sight.

I give the following formulæ as results of my investigation of the problem of surveying with the visual angle and stadia.

For a solution which shall be general and strictly rigorous, it must be observed that all the unrefracted rays which pass an object-glass cross at its optical centre, and that the vertex of the visual angle is at this point formed by lines produced through the glass from the spider-threads of the diaphragm. Also it must be observed that these threads approach, or recede from the object-glass by adjusting the focus, which changes the magnitude of the visual angle. The position in which the stadia should be held while taking an observation upon it should be first considered. If it could always stand at the same height as the telescope forming the visual angle, there would be no question as to a vertical position. But in practice almost every observation is taken while the central visual ray forms an angle with the plane of the horizon. The stadia may be inclined to a perpendicular to this ray, or it might still be held vertical. Sights may be attached for adjusting it to the former, or a plumb for adjusting to the latter position. In the former case the distance read would always be O A, Fig. 2, and $\text{OA} \cos \text{AOF} = \text{OF}$. But the stadia stands upon a stake at D: hence the required horizontal distance would be $\text{OG} = \text{OF} + \text{AD} \sin (\text{DAF} = \text{AOF})$; and the height $\text{GA}' = \text{OA} \sin \text{AOF} + \text{AD} \dfrac{\sin^2 \text{AOF}}{\cos \text{AOF}}$. A D being usually five feet or more, its correction would be too great to be neglected. Probably a more convenient formula for computing is obtained by always observing the stadia while vertical. As will be shown below, the reading will become O A′ very approximately by multiplying by cos A′ O F. This into the sine or cosine A′ O F, gives A′ G or O G; formulas which are convenient for logarithms. All the following investigations will be made for the stadia in a vertical position.

FIG 2.



Let us suppose the instrument centred over the point A, Fig. 3, and the stadia stationed at the point B.

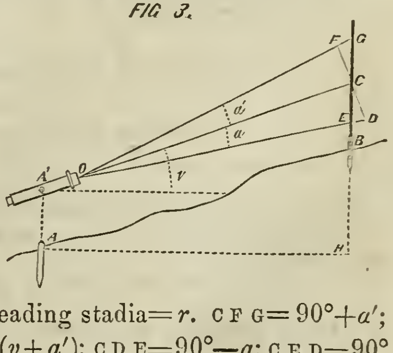
Let the required distance $\text{AH} = x$,
and height $\text{HB} = y$.

Let $v =$ the angle of O C with the horizon, and

$r =$ reading of the stadia.

Let the telescope be provided with a reticule of one vertical and three horizontal threads forming two partial visual angles $a\,a'$.

FIG 3.



Then $\text{FCG} = \text{ECD} = v$; and $\text{GE} =$ reading stadia $= r$. $\text{CFG} = 90° + a'$; $\text{CGF} = 180° - v - (90° + a') = 90° - (v + a')$; $\text{CDE} = 90° - a$; $\text{CED} = 90°$

—$(v-a)$. We have CF : CG :: $\sin 90° - (v+a') : \sin 90° + a' :: \cos (v+a') : \cos a'$, whence

$$\mathrm{CG} = \frac{\mathrm{CF} \cos a'}{\cos (v+a')}. \text{ Similarly } \mathrm{CE} = \frac{\mathrm{CD} \cos a}{\cos (v-a)}, \quad . \qquad (1)$$

and we will have

$$\mathrm{EG} = \mathrm{CG} + \mathrm{CE} = \frac{\mathrm{CF} \cos a'}{\cos (v+a')} + \frac{\mathrm{CD} \cos a}{\cos (v-a)}.$$

Put CD : CF :: $m : n ::$ tang a' : tang a' $\therefore$ $\mathrm{CD} = \mathrm{CF}\,\frac{m}{n}$ $\quad . \qquad (2)$

Then

$$\mathrm{EG} = \mathrm{CF}\left(\frac{\cos a'}{\cos (v+a')} + \frac{m \cos a}{n \cos (v-a)}\right) = \mathrm{CD}\left(\frac{n \cos a'}{m \cos (v+a')} + \frac{\cos a}{\cos (v-a)}\right)$$

$$\therefore\ \mathrm{CF} = \frac{\mathrm{EG}}{\left(\frac{\cos a'}{\cos (v+a')} + \frac{m \cos a}{n \cos (v-a)}\right)},$$

$$\text{and } \mathrm{CD} = \frac{\mathrm{EG}}{\left(\frac{n \cos a'}{m \cos (v+a')} + \frac{\cos a}{\cos (v-a)}\right)}.$$

But CF+CD = reading of the stadia corrected to FD,

$$\text{corresponding to dist. } \mathrm{OC} = r \left\{ \frac{1}{\frac{\cos a'}{\cos (v+a')} + \frac{m \cos a}{n \cos (v-a)}} + \frac{1}{\frac{n \cos a'}{m \cos (v+a')(v-a)} + \frac{\mathrm{c}}{\cos (v-a)}} \right\} = \frac{r\,(m+n)}{\frac{n \cos a'}{\cos (v+a')} + \frac{m \cos a}{\cos (v-a)}} \cdot \quad . \qquad (4)$$

which is the reading of stadia EG reduced to DF, without regard to the relative values of $a\,a'$.

This corresponds to the distance CO.

Let the quantity OA′, intervening between the object-glass and YS, $= c$ then

$$\mathrm{A'C} = \mathrm{OC} + c = r\,\mathrm{M} + c = \frac{x}{\cos v} = \frac{y}{\sin v}, \quad . \quad . \qquad (5)$$

$$\text{making } \mathrm{M} = \frac{m+n}{\frac{n \cos a'}{\cos (v+a')} + \frac{m \cos a}{\cos (v-a)}},$$

which would always be correct for A′C if the angle $(a+a')$ could be constant. Some prefer to make no adjustment of the focus which secures a constant visual angle. Then

$$x = \mathrm{A'C} \cos v \text{ and } y = \mathrm{A'C} \sin v. \quad . \qquad (6)$$

But I design to make the solution general for a perfect adjustment of the focus.

Let us consider then a third correction due to adjustment of focus. Call this correction z. Then, instead of (5) we have

$$\text{A}'\text{C}=\frac{x}{\cos v}=\frac{y}{\sin v}=r\,\text{M}+c+z=\text{S}+c. \qquad . \qquad (7)$$

We have yet to determine z.

We have for the general equation of the varying focus of a convex lens

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{\text{S}},\ \text{or}\ u=\frac{\text{S}\,f}{\text{S}-f}, \qquad . \qquad . \qquad (8)$$

in which if f=principal focal length, u=focal length for an object at a distance S.

For our case let S always be regarded as equal O C, Fig. 3. Measure a distance which on the horizontal plane A H Fig. 3, $=x'$, and for this let $z=o$ when $v=o$, then

$$(\text{A}'\,\text{C})=x'=r'+c=\text{S}'+c, \qquad . \qquad . \qquad (9)$$

And for any other point where the stadia may be set we will have the expression equation (7); and

$$\text{S}'=r', \qquad \text{S}=r\,\text{M}+z, \qquad . \qquad . \qquad (11)$$

r' being that particular reading for the stadia at a distance x'. We will have two values of u Eq. (8)

$$u=\frac{\text{S}\,f}{\text{S}-f}\ \text{and}\ u'=\frac{\text{S}'\,f}{\text{S}'-f} \qquad . \qquad . \qquad (12)$$

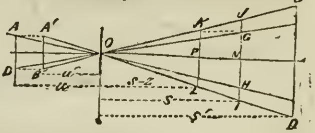
in which if S is less than S$'$, u' is less than u.

In Fig. 4, if O be the object-glass; A$'$D$'$ and A D the positions of the spider lines for objects at distances S$'$ and S, we will have, as will be plain by making A$'$ O coincide with O B, and A O with O H,

$$u:\,u'::\,\text{S}:\,\text{S}-z,\ \text{or}\ u'\text{S}=u(\text{S}-z); \qquad . \qquad (13)$$

since S would be the reading I J, corresponding to the distance O N, and S$-z$ the reading N G or K L, or distance O P if there were no correction for change of focus. Substituting in (13), u and u' from (12), S$'$ and S from (11), and reducing we get

FIG 4.



$$z=f\left(1-\frac{r\,\text{M}}{r'}\right), \qquad . \qquad . \qquad (14)$$

This in (7) and reduced gives

$$\text{A}'\text{C}=r\,\text{M}\left(1-\frac{f}{r'}\right)+c+f \qquad . \qquad . \qquad (15)$$

If we make $v=o$ and $r=x'-c=r'$, we have A$'$C$=x'$. Make $r=o$; then A$'$C$=f+c$. But we see r only equals the distance read when $r=r'\left(1+\frac{c}{f}\right)$ $\frac{3}{2}r'$ nearly. But in making the stadia originally it is convenient to have the reading equal the true distance x'. And as it is proposed to make the stadia a scale of equal parts, the readings from different scales will be proportional to those scales. We may then put $r'+c=\text{R}'=$ reading. Then we will have

$$r:\text{R}'-c::\text{R}:\text{R}', \text{ or } r=\text{R}\left(1-\frac{c}{\text{R}'}\right), \quad . \qquad (16)$$

which combined with (7), (9), (11) and (12) give

$$(\text{A}'\text{C})=x'=\text{R}'=\text{S}'+c,\ \text{A}'\text{C}=\frac{x}{\cos v}=\text{R}\left(1-\frac{c}{\text{R}'}\right)\text{M}+c+z=\text{S}+c,$$

$$z=f\left(1-\frac{\text{R M}}{\text{R}'}\right)=f\left(1-\frac{\text{R M}}{x'}\right), \quad . \qquad (17)$$

and $$\text{A}'\text{C}=\frac{x}{\cos v}=\frac{y}{\sin v}=\text{RM}\left(1-\frac{c+f}{x'}\right)+c+f. \qquad (18)$$

It sometimes happens that we wish to use a stadia whose divisions are too great or small, when it becomes necessary to multiply the reading by a co-efficient which will correct it. Let e represent this co-efficient. We will then have, for $\text{M}=$unity, $\text{R}e=x'=\text{R}'e$, $\therefore e=\frac{x'}{\text{R}'}$, and (18) becomes

$$\text{A}'\text{C}=\frac{x}{\cos v}=\frac{y}{\sin v}=e\text{RM}\left(1-\frac{c+f}{x'}\right)+c+f. \qquad (20)$$

This is the formula required. If $e=$unity, and $v=o$ or $\text{M}=$unity, and $\text{R}=o$, $\text{A}'\text{C}=f+c$; that is, when the stadia is at a distance f from the object-glass, or at its principal focal distance, the eye-piece and diaphragm are an infinite distance away, and the visual angle $(a+a')=o$. Consequently the reading must be zero. Make $\text{R}=\text{R}'$, then $x=\text{R}'=x'$ as it should, since at this point we desire that the reading should become the correct distance.

The two variables a and a' are yet to be considered. We have, Fig. 3.

$$\tan a_1=\frac{\text{C D}}{\text{O C}}=\text{C E}\frac{\cos(v-a_1)}{x'\cos a_1}\cos v,$$

$$\tan a'_1=\frac{\text{C F}}{\text{O C}}=\text{C G}\frac{\cos(v+a'_1)}{x'\cos a'_1}\cos v,$$

a_1 and a'_1 being the angles when $\text{R}=\text{R}'$; and CE, CG, absolute quantities measured upon the stadia. We also have, Fig. 4.

$\text{tang}\ a:\text{tang}\ a_1::u':u$, or $\text{tang}\ a=\text{tang}\ a_1\ \frac{u'}{u}$, and $\text{tang}\ a'=\text{tang}\ a'_1\ \frac{u'}{u}$, which become known by substituting for u, S and z.

These formulas are hardly ever necessary except perhaps for making the stadia originally. The following may be of use when our base is not on a level plane. Let $\text{D}=$amount intercepted by the visual angle at a horizontal distance x', and with a vertical angle v; and $d=$ the amount which would be intercepted if $v=o$. Then

$$\frac{d}{\cos v} = \mathrm{D\,M} + z = \mathrm{D\,M} - f\frac{\mathrm{D\,M}}{d} + f,$$

since d corresponds to x' and D to R in (17),

$$\therefore\ d^2 - d\,(\mathrm{D\,M} + f)\cos v = f\,\mathrm{D\,M}\cos v$$

If $v=o$, M $=$ unity and $d=\mathrm{D}$.

The stadia may be divided into such a variable scale as to make its own corrections for adjustment of focus. To make such a stadia, let the amount intercepted by the visual angle at a distance $x'=1000$ ft., be measured; then the amount intercepted at 100 feet equals that at 1000 feet diminished by $z=f\left(1-\frac{100}{1000}\right)\quad \frac{9}{10}f$; or $\frac{9}{10}f\tan(a+a')$ in absolute measure.

In practice there are approximate formulas which are sufficiently accurate for reducing field notes.

Usually $a=a'$ nearly, and by neglecting them altogether we introduce an error proportionate to a direct function of v, of only about $\frac{1}{1000}$ for $v=26°$. Hence dropping a and a' from (18) we get

$$x = \mathrm{R}\cos^2 v\left(1-\frac{c+f}{x'}\right) + (c+f)\cos v, \tag{21}$$

$$y = \tfrac{1}{2}\mathrm{R}\sin 2\,v\left(1-\frac{c+f}{x'}\right) + (c+f)\sin v, \tag{22}$$

that is,—to reduce observations upon a stadia which is uniformly divided, and for the focus in adjustment, *we will have the horizontal distance equal the reading, multiplied into a constant and the square of the cosine of the vertical angle, plus a constant into the cosine of the vertical angle;—and the height equal the reading into a constant and the sine of twice the vertical angle, plus a constant into the sine of the vertical angle.*

Values of $(c+f)$ (sine or cosine) may be arranged in a table. Also $1-\cos^2 v\left(1-\frac{c+f}{x'}\right)$ which will give a difference to multiply by R and subtract, which will usually be small. The quantity $\frac{\mathrm{R}}{2}\sin 2\,v$ $\left(1-\frac{c+f}{x'}\right)$ which is required more accurately may be calculated from a table, but generally there would be no advantage over the use of logarithms.

Formulas still less approximate than (21) and (22), but more convenient in practice are obtained by making $(c+f)=o$. We will then have

$$x_1 = \text{R} \cos^2 v, \quad \text{and} \quad y_1 = \text{R} \tfrac{1}{2} \sin 2v. \qquad . \qquad (24)$$

Subtracting these from (21) and (22)

$$x - x_1 = (c+f) \left(1 - \frac{\text{R}}{x'} \cos v \right) \cos v,$$

$$y - y_1 = (c+f) \left(\sin v - \frac{\text{R}}{x'} \cdot \tfrac{1}{2} \sin 2v \right).$$

If $x' =$ about 1000, as it should; and R never exceeding about 1500, the maximum values of the above differences is when $\text{R} = o$. If $v = o$ and $\text{R} = o$, $x - x_1 = (c+f) =$ max. $=$ about 18 or 20 inches. If $v = 10°$ which it hardly ever exceeds, and $\text{R} = o$, $y - y_1 = (c+f)\, 0{\cdot}17 =$ max. $=$ about 3 or 4 inches.

Hence, the error of x, in (24) *can never exceed* 18 *or* 20 *inches, nor that of y* 3 *or* 4 *inches for a telescope one foot in length kept in adjustment of focus.*

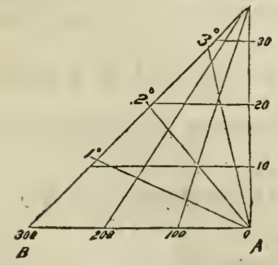
Equations (24) become more exact by adding the quantity $\dfrac{x' - \text{R}}{x'}$ $(c+f)$. Hence

$$x = \text{R} \cos^2 v + \frac{x' - \text{R}}{x'} (c+f) \cos v \text{ nearly,} \qquad (25)$$

$$y = \text{R} \tfrac{1}{2} \sin 2v + \frac{x' - \text{R}}{x'} (c+f) \sin v \text{ nearly,} \qquad (26)$$

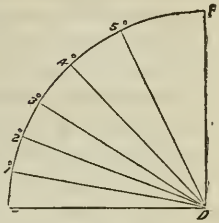
These formulas or even (24) are sufficiently exact for most cases of topography.

The quantity y_1 (eq. 24) may be determined graphically. There are several methods, two of which are given below.



Let AB, be the base of a triangle equally divided to represent feet$=$R by lines drawn from C. Draw lines parallel to AB intersecting AC at equidistant points to represent heights $= y$; and let lines drawn from A to BC represent angles v. These latter points of intersection must be calculated. To obtain y from this triangle, find the distance R on AB, then follow that line toward C till we meet the line of our vertical angle v; then following one of the lines parallel to AB to its intersection with AC, we will find the number corresponding to y. It may be convenient to be provided with a number of these triangles made for great and small values of R and v.

A quadrant which I understand was invented in Europe, answers a good purpose.



Let lines radiating from D represent the vertical angle v, and so divide E F that if R be taken from a scale and laid off from D on the line representing v, then the vertical distance above ED to that point measured on the same scale should $= 10y$.

This quantity divided by ten divides the error of the operation by ten. Five quadrants are required to reach $v = 45°$. The first, for the quantity $\frac{1}{2} \sin 2v$, ends with $v = 5° \, 46' \, 6{\cdot}5''$, where $10\,y = \text{R}$. The next quadrant gives quantities from zero up, which must be added to R and the whole divided by ten. For the third quadrant we must add 2 R &c. The second quadrant ends with $11° \, 47' \, 20{\cdot}7''$. The third with $18° \, 26' \, 5{\cdot}8''$. The fourth with $26° \, 33' \, 54{\cdot}2''$. The fifth with $45° \, 0' \, 0''$.

For leveling purposes the index error of the vertical limb should be known, and the stadia should have some point to be easily distinguished, to be used for adjusting the vertical angle before taking its reading. One of the spots which mark the 100 feet as A or B Fig. 1, and about the height of the instrument, may be painted red. The plumb-bob of the instrument may be suspended by a chain, or something more stable than a chord, to be used to determine the height of the instrument. The chain may be provided with hooks corresponding to 10, 20, &c. feet on the stadia, which will tell what point above or below the red target upon the stadia to sight at. The height of instrument may also be found by a tape-line.

For taking back sights a "barber's-pole" is useful, painted with alternate black, or red and white divisions, corresponding in length to those of the stadia, from which to count the 100 feet, to secure the observer against mistakes.

If it is required to make the stadia perpendicular to the line of sight when read; we will have M, Eq's (5) and (20), = unity. We must then add the quantity depending upon A D, Fig. 2. Thus Eq's (24) become

$$x_1 = \text{R} \cos v + \text{A D} \sin v, \qquad y_1 = \text{R} \sin v + \text{A D} \frac{\sin^2 v}{\cos v}.$$

The quantities depending upon A D may be tabulated.

For the Journal of the Franklin Institute.

Papers on Hydraulic Engineering. By SAMUEL McELROY, C.E.,

Continued from Vol. xlvii, page 11.

No. 5.—*Fire Service and Hydrants.*

The value of water supply, for fire service, is one of the strongest arguments usually presented for its introduction; an argument which gains force by careful attention to the disproportion between annual fire loss and cost of water administration. It is not uncommon in city experience, that a single conflagration should much exceed in pecuniary loss, the entire cost of an ample supply, or should be so much aggravated through defective supply, as to exceed largely the cost of proper improvements; and while annual fire statistics are counted by millions, expenditures for the preventive, are counted by thousands and hundreds of thousands. The loss by fire in Philadelphia, in 1862, was $450,176; the loss reported in New York for the six months ending May 31, 1864, was $2,512,696, or about one-ninth the entire cost of the original works, while the cost of annual administration, exclusive of extension, was $108,760; the loss at Cleveland in 1861-2, was $227,000, the original cost of water supply being $550,000 and the annual administration, without extensions, $9,117; and cases of special conflagrations might be cited, which, as at Troy, or Albany, sweep a large part of a whole city out of existence, and are registered in the columns of millions. While a part of this article was being written, the telegraph flashed an account, across the wires, of $750,000 loss, in one night, on the American Hotel block at Buffalo, exceeding by $220,000 the cost of her water-works, on which property, the annual city tax alone, far exceeded the whole annual expense of water administration.

In the Paper on Distribution, Vol. xliv, pages 145 and 217, a brief allusion was made to hydrants, under the head of "appurtenances;" this subject,in connexion with that of fire-service,is so directly associated with the theory of adequate water supply, for ordinary and extraordinary delivery, as to require a systematic discussion, which follows as a proper sequel to that of distribution, and includes its more important features.

With this object, we propose to examine, in their order, and in brief, the general *office* and *methods of distribution systems*, the *progress of fire-engines*, the *conditions of fire service*, and its *improvement*, the *defects of distribution* and proposed corrections, the *progress of fire-hydrants* with their *contingencies* and *defects*, and the *improvements* suggested.

Office of Distribution.—Water is required for drinking, cooking, washing, bathing, street-cleaning, and for extinguishing fires, as prominent private and public applications for individual comfort and safety and general health; and it fulfils these several offices, through various mechanical appendages to the distribution system, which are known as faucets, turn-cocks, stand-pipes, hydrant-pumps, drinking-hydrants, fountains, horse-troughs, street-washers, fire-plugs and various other names, characteristic of their special uses, and which are very much diversified in form and action. Of this entire class we have to do at present with but two or three members, in which certain adaptations of form to use, and its contingencies, are of special consequence.

Methods of Distribution.—The operation of all distributing appurtenances is directly affected by the character of the supply to which they are attached, whether of the Low Service, Intermittent or Constant High Service, there being essential differences of method in different localities, in this respect.

The Low Service is defined by the use of the supply, under very moderate head, or without pressure, after its reception at the place of use. This was the general nature of ancient supplies, though modified by special exceptions, and prevailed, although the principle of conveyance under excessive pressure was fully understood and practised on the aqueduct lines, and in cases of city distribution, so far as the feeding and service mains were concerned.

As we have noticed in the paper on Reservoirs, (Vol. xliii, page 291,) the reservoir conduits of Rome, as one example, were arranged to supply the public fountains first, the public baths next, and lastly the several dwellings.

A greater part of the citizens resorted to the public fountains for domestic supply, as is now customary in many countries of the Old World, while in the courts of the private palaces and other luxurious dwellings, fountains were kept in play and cisterns were constructed for special reserve supply. The various public and private fountains and cisterns were therefore used as receptacles, from which the ordinary supply for domestic uses was taken by hand.

These fountains are in such admirable preservation at the present day, as to attract the attention of travelers, furnishing a luxurious addition to the attractions of the ancient city.

Of the manner in which Pompeii was supplied, the following quotation, by Mr. Earnshaw of the Cincinnati water-works, is sufficiently concise:

> "The letting out of the public water to private persons was a source of revenue; the supervision of which was entrusted to an officer of high rank, and many precautions were taken to prevent fraud in this matter. The aqueducts were each charged with a certain number of supply pipes, and no new pipe could be inserted without a special application to the Emperor. Permission being obtained, the applicant was assigned a calix, as it was called, of the assigned dimensions. This was a brass measure fixed in the castellum or reservoir, the diameter of which regulated the quantity of water which could pass through it, and for which the applicant was charged. Beyond the calix, the pipe was private property, but more effectually to prevent fraud, it was enacted that for a distance of fifty feet, the calix and the pipe should be of the same diameter. The right to a supply of water was strictly personal, not attached to houses, and the supply was cut off at every change of ownership, and the right previously granted, was sold by the superintendents to the highest bidder. Those inhabitants whose means of interest were insufficient to obtain a private supply pipe were obliged to carry their supply from the public fountains."
> —*Library of Entertaining Knowledge.*

Not only did this general system prevail in the supplies of the Old World, but it is common to many cities of the present time, in which the service of the water carriers are almost entirely relied upon for domestic uses; in the present century, cities like Paris have depended on such processes of daily house supply, while in London, the Low Service is a very recent characteristic of its distribution, and so of many other European towns.

The ancient system, however, was constant in its operation, and available at all times when required. It was reserved for modern times to inaugurate a change, which added to the disadvantages of the Low Service, the ill-advised and miserly features of the *Intermittent System.*

Under this method, as at London, the several companies each subdivided its general district of supply, into minor districts, of which but one was supplied at a time, and at intervals varying from one to three days, the times of such supply being a limited number of hours in length. The consumers were therefore obliged to find special storage for their supply, in tanks, cisterns, tubs, pails and the like, to carry them through the intervals, and added to the objectionable features of the Thames and New River water itself, the grave objections which pertain to such kinds of storage. The effects on fire supply are referred to by Mr. Matthews, in his *Hydraulia*, edition of 1835, page 71, as follows:

> "Formerly the Water Companies of the metropolis did not profess to supply higher than the ground floor of any house, and therefore it was not their practice to keep the pipes constantly full of water, both day and night, as at present is the case. In fact, prior to the adoption of the effective system now pursued, they found it necessary to be very economical in its distribution; and during the nights the valve at the upper end of the mains was usually shut, so that when a fire happened, however alarming or extensive it might be, it was necessary to send a messenger to the person stationed at the New River head, or some of the other sources, to apprise them of the accident, before a supply of water could be obtained. Watchmen were likewise employed for the particular purpose of being constantly on the look-out for fires, and as soon as discovered, to convey with the utmost speed, information to the respective water-works, of the precise place where they had occurred. But the delays usually and unavoidably attendant upon this practice, were productive of serious evils, and the destructive element would often make dreadful havoc, before any water could be procured to diminish or destroy its power."

The improvement in maintaining a charge of water in the street main here referred to, dates back to a period earlier than 1818, for some of the London Companies, as will be noticed in an extract from a letter of J. Walker, C.E., to Frederick Graff, C.E., engineer of the Fairmount Water Works, dated London, April 6, 1818:—

> "After the district is supplied, it is desirable that all the cocks on the mains be opened; and that the principal mains be always kept full of water in case of fire, an inconvenience arising from this is that if *ball cocks* in the houses which are supplied directly from the mains are not attached, or are not kept in repair, a great waste of water is the consequence; as the water is laid on to the houses throughout the whole of the day. To remedy this it is not unusual to run a pipe of supply parallel to the main, with communications and stop-cocks at proper distances between the main and it; and to let all the private pipes communicate with the smaller pipe only. The water is thus laid on to the houses in the streets through which the main runs, for a limited time only, in the same manner as in the cross streets; and the main is not allowed to be broke into for private pipes."

The *Constant High Service* by which the distribution mains and pipes are always kept under the reservoir head, is not without a number of examples in Europe, as at Glasgow, Hamburg, and some other cities, but with us, is so universal, and was so early introduced, as to merit the title of the American System; its European use being, in many cases, the result of our example on recent works.

The differences in manner of use and of pressure contingent on these differences of system, affect all classes of distributing appurtenances.

Of fire-hydrants in particular it may be said that their office has been of a much less important character under the Low and Intermittent Systems than under that of continual and severe pressure, which requires a more careful use and a much more careful construction.

Progress of Fire Engines.—In connexion with the effects of method in distribution, we have also to consider those changes in the manner of extinguishing fires, which have served to give increased importance to the character of our fire-hydrants, and which have also been affected by processes of supply.

The records of skill among the ancients, in hydraulic machines, are full of interest, and the drawings and accounts of water clocks, pumps, engines and other ingenious applications in hydrodynamics, show an advanced knowledge of the science. From these records it is known that much attention was paid to precautions against fires and their extinguishment by the organization of special companies and the use of forcing engines. One of these, as used in Egypt, in the second century before Christ, contains an air chamber in the discharge tube, and is in many respects similar to the modern type, though without suction apparatus, or supply independent of buckets or equivalent hand labor from the fountains and cisterns of the time, and it is evident that while powerful pumping engines were in use among the ancients, such use was more particularly confined to military operations, and the ordinary fire engines, down to a very modern date, were of small size and limited power, the chief reliance being placed on manual labor, with buckets, ladders and hooks.

The modern fire engine of any capacity which entitles it to consideration, dates about the year 1729, according to Ewbank, (*Hydraulics*, page 334,) as the invention of Richard Newsham, an English engineer. This engine is of the "goose-neck" pattern, with a pair of single acting pumps worked by chains attached to a double sector, with a long vertical air chamber, and a suction tube.

Small engines, fitted with leathern hose for delivery, and afterward for suction, were introduced in Amsterdam in 1672.

In the city of New York, about 1648, ladders, hooks, and buckets, were imported from Holland, for fire purposes; and the Newsham fire engines were ordered for city use in 1730, being the first of the class on record. In many cities of the United States, within the present century, the fire apparatus has been equally primitive with that of New York before 1731, as is the case at present, in many villages and small settlements.

The most important addition to our fire- departments, however careful and costly the arrangement of their hand-engines, has been recently made by the successful introduction and adoption of steam fire engines. The arguments in their favor are evident, in city experience, on account of their superior power and endurance, and the remedies they offer, at no distant day, to the growing evils of the volunteer system, have made it certain that all the details of engine supply must be remodeled to meet the conditions of this novel addition to the class under discussion.

The use of stationary steam pumps for fires and safeguards, is no novelty in many of our cities. In New York, with the gradual loss of head in the city below 14th street, hotels and factories have been compelled to adopt this precaution, on an extensive scale ; the pumping department of the St. Nicholas Hotel, on Broadway, with its connected branch lines of delivery throughout the house, is arranged with large outlay in cost, and with special completeness in all its details ; such expenditures throughout the lower city evince a full conviction of the necessities of the time, and the imperfections of the water supply proper. Of such a provision applied to public uses, the Report on Water Supply of Providence, R. I., thus speaks :

> " In this city, street pipes are connected with the steam pumps of various factories. By the report of the Fire Department, submitted in May of this year,(1856,) it appears that up to that time 4780 feet of iron pipes had been laid, and 25 hydrants established in connexion with them. Now this system of using steam engine power for forcing water through pipes laid down under the streets, to be used at fires, once commenced, has got to be extended over the whole city."

The Report then very properly argues the superior economy of a reservoir supply.

Although Mr. Ericsson obtained the prize of the Mechanics' Institute of New York, in 1840, for the best plan of steam fire engine, these engines have not taken a place in practical operation until more than 10 years later. Having various mechanical difficulties to perfect, in which direction much is yet to be accomplished, and having bitter and powerful prejudices to overcome, they have been slow in gaining a position from which they cannot now be dislodged. Their correctness of principle is established, and when their construction in detail is more carefully based on the laws which govern all pumping engines, their perfection of performance will be duly attained. Without pausing to discuss this matter, it is enough to understand that this element of fire service must be fully developed by adequate details of supply.

It follows, then, from this sketch of different systems of service and of progress in fire-engines, that fire-hydrants, as we have them, are creations of the American system and of the nineteenth century, since it has been reserved for the more recent conditions of service, to call into action appurtenances specially adapted to their requirements.

Conditions of Fire Service.—To those who have given this matter attention, it is evident that fires may have various producing causes, and in their extinction may involve various degrees of effort. Fires arising from causes which are readily perceived, differ from those which may be for some time secretly at work ; and fires which increase in fury by degree, differ from those produced by violent and sustained agencies ; those occurring in buildings of careful construction and easy of access, differ from cases in inflammable structures, or those excessively high, or on elevated ground. There are fires, therefore, which with any moderate exertion are easily subdued, and there are those which will tax all the energies of the best organized department and the most perfect service, in their swift and destructive progress. As there may be a time when a small jet of water will prove an adequate extinguisher, so there may be a time when water will but add fuel to the flames.

The following abstracts of causes of fire, embody statistics, which are sufficient for our present argument under this head:

Average of 17 years experience in London, in causes of fire.

Causes.	Cases.	Causes.	Cases.
Unavoidable accident, .	27	Defective hearths, . .	$1\frac{1}{5}$
Ignited apparel on the person,	4	Hot cinders put away, .	3
Accidents with candles, .	169	Lamps, . .	5
Palpable carelessness, .	18	Slaking lime, . .	4
Children, playing with fire,	14	Drying linen, . .	30
Drunkenness, . .	5	Lucifer matches, . .	11
Fire heat in manufacturing processes,	26	Ovens, . .	7
Fire sparks, . .	21	Reading and smoking in bed,	$1\frac{1}{5}$
Fire works, . .	4	Loose shavings, .	20
Fires on hearth, . .	7	Spontaneous combustion,	13
Defective or foul flues, .	75	Defective or overheated stoves,	37
Incautious fumigation, .	3	Tobacco smoking, .	14
Gas, . .	46	Suspicious, .	7
Gunpowder, . .	$1\frac{1}{5}$	Wilful, .	12

The results are thus given for the same average:

	Cases.
Slightly damaged, ...	470
Seriously damaged, ...	212
Total loss, ...	26
Insured, ...	478
Uninsured, ...	230

For the six months ending May 31, 1864, in New York, of 195 fires and alarms reported, the causes of 125 are thus analyzed:

Causes.	Cases.	Causes.	Cases.
Kerosene oil, .	3	Grates, .	4
Benzine, .	2	Hot air furnace and registers,	4
Ashes, .	2	Dripping fat, .	2
Matches in hands of children,	17	Stove and stove pipes, .	16
Candles and lamps, .	14	Window curtains, .	7
Chimney flues, .	22	Forges, .	2
Drying rooms, .	2	Tin roofers' fire-pots, .	2
Fire places, .	3	Gas stove, .	1
Sparks on roofs, .	2	Intoxication, .	3
Furnaces, .	3	Steam boiler explosions, .	2
Gas and gas-lights, .	12		

Deaths by fire.

In burning buildings, . . .	3
Explosions of kerosene oil, . . .	3
Other causes, ...	55

The inference from these chapters of investigated and analyzed cases, where the causes have been determined officially, makes it plain that the greater part of the fires might easily have been prevented by means which should be readily within reach; and while the second London chapter conveys a singular lesson on the great disproportion of insured premises, it more fully on this account, argues the need of prompt remedies for suspicious cases; it is to be observed, also, that the total and serious losses are but fifty per cent. of the entire class.

Aside from general statistics, many prominent instances will occur at once to memory, which illustrate either the want of a remedy immediately at hand, or the fatal effect of inadequate appliances.

Cases abound, similar to that of the Jersey City Ferry buildings, where a supply comparatively prompt, has yet proved entirely inadequate in force, from the hydrants, to reach the roofs, which were less than half the reservoir level.

The prominent lesson of our fire experience is a continuous comment on the necessity of prompt remedies; this is particularly true of wilful fires and those of violent causes, and it involves a question of advantage as to time of application and as to adequate power. The contingencies often place life in danger, no less than property, and delays frequently result, in the case of partial losses, in more damage from water than from fire.

In the great majority of cases with us, and in Europe, the entire reliance is placed on the fire department, whether under the control of the Insurance Companies as in London, or the city government, as commonly arranged. Those cases are exceptional which provide for fire service by superior reservoir heads and careful details of special service, and practically dispense with fire engines.

Nor does experience justify the abandonment of a fire service adapted to the management of serious conflagrations, whatever may be the facility for hydrant supply, since such cases demand a concentration of effort and an expenditure of power, which cannot be otherwise had, and fire service generally requires something more than water-jets. But while we do not argue the possibility of dispensing with this provision for cases of more than ordinary character, it is clear that within a certain limit, provision is important for remedies of a more simple character, and more immediately available.

With us, in large cities, where watchmen are constantly on duty in elevated places, and police telegraphs are carefully maintained, it will still consume from 3 to 5 minutes to give a public alarm, designating by bell strokes, the special district where a fire has occurred; with an average speed of ten miles an hour for the engines, and an average run of a mile and upwards, the time of engine travel will be from 8 to 12 minutes; and the placement of engines on the ground and commencement of supply will take from 5 to 10 minutes, making from 16 to 27 minutes lapse before a stream is at work.

Testimony on this point at London, where great care is observed at the engine houses to keep a force on the alert, shows that from 30 to 40 minutes generally elapse before the engines are fully at work. With us the time varies considerably, but it must be admitted that the shortest period above estimated is frequently exceeded.

In most cases this period will suffice for considerable headway; in experience this is manifestly so, fires being well under way, as a rule, before the first engine stream is opened. This very necessity of delay, plainly permits an amount of damage, which could not otherwise occur. It is given as the result of long continued observation, by those whose practice qualifies them to judge correctly, that not less than two-thirds of our fires become serious from the absence of prompt remedies.

With the fire department at work, as usual, not only on the burning premises, but those adjacent, or on the burning portion of the premises, it follows that large quantities of water are often used in actually destroying property, and such destruction forms no small part of insurance restitution or personal loss.

It is also clear from the painful chapters of fire casualty, that much of this might be spared with a more prompt relief; every moment of delay in such cases being fatal in its effects.

Delays may not only be inherent in dependence on the fire department, but this service may be embarrassed by deficiencies in kind or amount of power, or in the distribution service, or by contingencies of the time. Cases are not uncommon in which conflagrations have reached a point where fire engines give way to gunpowder explosions, or where severe frost has made hydrants, hose, and machines useless appurtenances; but it is the province of true wisdom to anticipate all such casualties, so far as human foresight or human experience may avail.

From these conditions we see that the management of fires, involves proper attention to two distinct processes; one of which must meet those cases, which may be speedily corrected, and the other must guard those more serious cases, which require all the appliances of an organized and powerful department. These processes should be distinct in provision though capable of united action.

Improvement of Fire Service.—The previous investigation makes it plain that very great benefits would be secured by the addition to our ordinary fire service of a method fully capable of more prompt application than is now possible. This method involves the use of a hose and hydrant service, before the arrival of the fire engines, and must therefore be an addition to the ordinary fire department.

The introduction of water supply in our larger cities, has been followed by the organization and equipment of hose companies, with the idea of such an independent method of service, in part, and as an improvement on the old system of hose carts or reels, attached to the fire engines. But it is a matter of fact, in practice, and of necessity from their company organization, that hose carts of the improved school, are no less tardy in coming on the ground and into action, than the engines, and by consequence, the chief feature of improvement must be differently arranged to secure the leading element of promptness for those numerous cases which specially require it.

The following tables of statistics from the Brooklyn Reports, embody interesting information as to the average amount of hydrant and hose service, required in a period of three years.

Brooklyn Fire service in 1861, Piped District.

MONTH.	No. of fires.	Estimated damage.	No. of Hydrants used.	No. of Lengths of Hose used.	Whole time in use.		Average time per Hydrant.		
		Dollars.			h.	m.	h.	m.	s.
January,	6	15,725	26	. .	10	30		24	6
February,	11	7,455	44	548	16	14		21	22
March,	16	6,110	62	515	32	52		31	51
April,	9	1,725	26	143	2	20			20
May,	8	7,300	29	187	7	0		14	14
June,	3	1,400	17	142	1	0		3	9
July,	14	6,125	45	363	6	36		8	36
August,	12	8,075	44	332	55	25	1	15	34
September,	7	34,255	31	449	28	52		55	52
October,	4	4,600	12	144	8	40		43	20
November,	4	1,400	18	159	13	0		43	20
December,	2	2,500	12	57	12	55	1	4	35
	96	96,670	366	3039	195	24			
Per fire,			3·81	31·5					

Brooklyn Fire service in 1862, Piped District.

MONTH.	No. of fires.	Estimated damage.	No. of Hydrants used.	No. of Lengths of Hose used.	Whole time in use.		Average time per Hydrant.		
		Dollars.			h.	m.	h.	m.	s.
January,	10	18,525	44	290	72	55	1	39	25
February,	9	1,810	36	242	17	35		26	
March,	8	7,300	40	315	33	10		49	45
April,	5	7,700	25	253	7	5	1	25	
May,	14	347,970	68	847	201	39	2	59	50
June,	8	14,250	43	264	65	45	1	28	12
July,	3	10,000	14	84	24	10	1	43	
August,	3	1,000	7	73	1	33		13	17
September,	1	2,500	5	45	1	25		17	
October,	0	6,650	38	290	6	30		10	10
November,	7	4,300	23	228	4	25		11	21
December,	5	1,500	16	113	1	30		5	10
	83	423,505	359	3044	437	42			
Per fire,			4·20	36·3					

Brooklyn Fire service in 1863, Piped District.

MONTH.	No. of fires.	Estimated damage.	No. of Hydrants used.		Whole time in use.	Average time per Hydrant.
		Dollars.			h. m.	h. m. s.
January,	5	3,500	18		13 25	44 13
February,	10	11,000	30		26 0	52
March,	14	18,500	50		8 50	10 30
April,	9	15,500	38		4 30	7
May,	8	7,500	38		5 10	8 6
June,	8	8,000	40		5 50	8 30
July,	10	100,000	45		8 30	11 20
August,	9	5,700	27		6 0	13 9
September,	6	85,000	70		13 30	11 4
October,	10	25,000	43		11 0	15 15
November,	6	2,500	24		6 30	16 6
December,	0					
	95	282,000	423		109 15	
Per fire,			4·45			

From these notes it appears that the average use of hydrants is about four per fire, and the average length of hose per hydrant somewhat less than 450 feet, the average length of time for fires being 2·71 hours, though the variations in such duration are considerable, as are also the respective amounts of damage.

The use, as here shown, of about 1700 feet of hose per fire, presents in resultant, excessive friction, a strong argument in favor of shorter intervals between hydrants, while it forcibly illustrates the superior effects of prompt service from improved hydrants and short lengths of hose; and herein is contained the system of improvement which a better fire service evidently demands.

This improvement, in our opinion, should consist in the subdivision of the present fire districts of any large city, into small sections through which the average running time, from hose station to extreme limit should not exceed three minutes, for a small, compact hose reel and hand-cart, which two men could easily manage; in addition, wherever it could conveniently be done, by arrangement with public spirited house occupants, or insurance stockholders, opposite hydrants, a couple of lengths of hose might be deposited in houses well known to the police and otherwise specially designated as such store houses; this need not be done on every block, but at intervals of several blocks, so as to control spaces not exceeding 1500 feet in length, and in some localities the interspaces might be greater; advantage should be taken of the present engine hose houses for use as such auxiliary stations.

In this way, by the employment of men, specially engaged in such preliminary fire service, who are always in the immediate vicinity of an alarm, and can know of it as readily as the police who now report fires to the nearest telegraph station, which reports to the proper office for a district alarm, and who can act in advance of the fire watchmen in their towers, the means will be provided for a prompt and effective application of remedies which are all the more effective from early use. These firemen, who might very properly be members of the district police, would find no lack of willing assistants, since fire alarms have a very peculiar eloquence to next door neighbors and are apt to speak in imperative moods. With such appliances at hand, the principal of prompt remedy might be fully developed, and in the case of more serious fires, the first engine on the ground would find a hose supply ready for its pumps. As this plan increases the number of hydrants, it would reduce the lengths of hose in use, and for the same number of engines at work, there would be a more abundant supply with less cleaning to do afterward. This last item is paid for now, at a very dear rate, and certainly would not cost any more, under the new arrangement; but the stock of hose would have to be increased and the number of hydrants, at a cost which the first fire prevented, would probably more than balance.

The expense of such an arrangement, which ensures one or more hydrant streams, within one quarter the time now wasted, and which will reduce the cost of insurance, the aggregate damage, and the contingencies of life lost, while it promotes a general sense of security, will be affected by the details of its application. With a paid fire department, as at Boston, the expense need not be increased, and by allotting a portion of the police force to this service, as organized in New York and Brooklyn, the increase of cost cannot be large, and one local advantage will ensue, in having a policeman or two, always located and easily found. Whether any such additional expense shall be borne by insurance companies or not, is a question of municipal policy which pertains to the entire use of water supply for insured buildings, and which admits arguments on both sides, since improved water supply always has been met by reduced insurance premiums, and all fire losses, whither indemnified or not to property owners, always exhaust a certain taxable property, which represents its proportion of municipal income and wealth.

Whatever may be the water pressure, it is evident that this addition to the method of fire service would be followed by immediate and important benefits; at the same time, it is evident that such auxiliary service might be made much more valuable, if all the details of distribution service were arranged with a distinct adaptation to such a system. What this line of improvement is, will therefore be properly discussed in the remarks which follow on the defects of distribution, and their correctives, and the progress, defects, and improvements of fire hydrants.

(To be Continued.)

For the Journal of the Franklin Institute.

The Radial Paddle-Wheel. By JOHN D. VAN BUREN, Jr., C. E., U. S. Naval Engineers.

(Continued from page 25.)

The Centre of Horizontal Effort.

Each elementary area dr impinges horizontally against the water with a relative velocity equal to $(rw\cos\varphi-v)$, and has an effective area opposed to the resistance in such direction equal to its vertical projection $dr\cos\varphi$. Hence, as before, the resistance opposed to the motion of the paddle in a horizontal direction, is

$$\int(rw\cos\varphi-v)^2dr\cos\varphi \qquad . \qquad . \qquad (a)$$

and the sum of the moments about c is, for all the paddles,

$$\Sigma\int(rw\cos\varphi-v)^2rdr\cos^2\varphi \qquad . \qquad . \qquad (b)$$

$r\cos\varphi$ being the arm of each elementary force.

Now let $X=$ distance from centre of shaft to point of application of resultant of all the horizontal efforts or resistances of the different paddles, *i. e.*, to the centre of horizontal effort of the wheel. Then since the moment of the resultant is equal to the sum of the moments of the components, we have

$$X\Sigma\int(rw\cos\varphi-v)^2dr\cos\varphi=\Sigma\int(rw\cos\varphi-v)^2rdr\cos^2\varphi \quad (8)$$

or

$$X=\frac{\Sigma\int(rw\cos\varphi-v)^2rdr\cos^2\phi}{\Sigma\int(rw\cos\phi-v)^2dr\ \ \cos\phi} \qquad . \qquad . \qquad (9)$$

where Σ signifies that the sum of all similar terms is taken.

Now putting N_1, N_2, &c., for the variable factors of the numerator, and D_1, D_2, D_3, &c., for the variable factors of the denominator, there results

$$X=\frac{N_1\cos^2\phi_1+N_2\cos^2\phi_2+\text{\&c.}}{D_1\cos\ \phi_1+D_2\cos\ \phi_2+\text{\&c.}} \qquad . \qquad . \qquad (10)$$

where

$$N=\int_{R_1}^{R_2}(rw\cos\varphi-v)^2\,rdr,\text{ and }D=\int_{R_1}^{R_2}(rw\cos\varphi-v)^2\,dr \quad (11)$$

Now for N and D we may use proportional quantities, and to find such we have

$$\frac{N}{D}=\frac{\int(rw\cos\varphi-v)^2\,rdr}{\int(rw\cos\varphi-v)^2\,dr} \qquad . \qquad . \qquad . \qquad (12)$$

This differs from (5) only in the position of $\cos\phi$ (a constant); and therefore, $\cos^2\phi$ in (6) being transferred from the last terms of numerator and denominator to the first terms of the same gives (12), or,

$$\frac{\mathrm{N}}{\mathrm{D}}=\frac{3(\mathrm{R}_2{}^4-\mathrm{R}_1{}^4)\cos^2\varphi-8(\mathrm{R}_2{}^3-\mathrm{R}_1{}^3)\mathrm{R}_2 m\cos\phi+6(\mathrm{R}_2{}^2-\mathrm{R}_1{}^2)\mathrm{R}_2{}^2m^2}{4(\mathrm{R}_2{}^3-\mathrm{R}_1{}^3)\cos^2\varphi-12(\mathrm{R}_2{}^2-\mathrm{R}_1{}^2)\mathrm{R}_2 m\cos\varphi+12(\mathrm{R}_2-\mathrm{R}_1)\mathrm{R}_2{}^2m^2} \qquad (13)$$

Therefore by taking for N the numerator, and for D the denominator, of (13), calculated respectively for the different paddles making the respective angles with the vertical of ϕ_1, ϕ_2, ϕ_3, &c., and substituting these values of N and D for N_1, N_2, &c., D_1, D_2, &c., in (10), we shall find X. But some parts of a paddle may have a less *horizontal* velocity than v; and then the resistance will evidently be *negative*, the water impinging against the paddle instead of the reverse. This negative sign will not appear in the value of N or D, for the *squares* of $(r\,w\cos\varphi-v)$ will always be positive. We have therefore to determine that portion of the paddle which has less horizontal velocity than v, and consider the paddle as two distinct paddles, one being the said portion having less horizontal velocity than v. This dividing line is readily found; for it is determined by the equation.

$$\mathrm{R}\,w\cos\varphi=v=m\,\mathrm{R}_2\,w$$

or

$$\mathrm{R}=\frac{m\,\mathrm{R}_2}{\cos\phi} \quad . \quad . \quad . \qquad (14)$$

R being its distance from C. For the upper portion of the paddle, considered as a distinct paddle, R must be put for R_2 in the expressions for N and D^1, and for the lower portion, considered as a distinct paddle, R must be put for R_1. This is the only change necessary.

Modulus of the Radial Paddle-Wheel.

The modulus is the ratio between the useful work and the total work of the wheel.

The total work of the wheel is the sum of all the normal resistances acting with a velocity equal to the rotary velocity of that point at which we may consider all the normal resistances to act as a single force producing the same moment about c.

The useful work is the sum of the horizontal resistances acting with a velocity $v=m\,\mathrm{R}_2\,w$.

Let $\mathrm{H}=$ distance from centre of shaft to the point at which all the normal resistances may be considered to act as a single force.

$$\therefore \mathrm{H}\,\Sigma\int(rw-v\cos\varphi)^2dr=\Sigma\int(rw-v\cos\varphi)^2rdr$$

or

$$\mathrm{H}=\frac{\Sigma\int(r\,w-v\cos\varphi)^2rdr}{\Sigma\int(r\,w-v\cos\varphi)^2\,dr} \quad . \quad . \quad . \qquad (a)$$

The point determined by H has a rotary velocity of $H\,w$; hence the work of the normal resistances is

$$H w\, \Sigma \int (r w - v \cos \varphi)^2\, d r$$

The work of the horizontal resistances is

$$v\, \Sigma \int (rw \cos \varphi - v)^2 dr \cos \varphi = m R_2 w \Sigma \int (rw \cos \varphi - v)^2 dr \cos \varphi \quad (b)$$

$$\therefore \text{ Modulus} = M = \frac{m\, R_2}{H} . \frac{\Sigma \int (rw \cos \varphi - v)^2\, dr \cos \varphi}{\Sigma \int (rw - v \cos \varphi)^2\, dr}$$

or (*a*)

$$M = m R_2 \frac{\Sigma \int (rw \cos \varphi - v)^2\, dr \cos \varphi}{\Sigma \int (rw - v \cos \varphi)^2\, r dr}$$

$$= m\, R_2 \frac{D_1 \cos \varphi_1 + D_2 \cos \varphi_2 + \&c.,}{N' + N'' + \&c.,} \quad . \quad . \quad (15)$$

when $N =$ integral of the numerator of (5), or,

$$N = 3\,(R_2^4 - R_1^4) - 8\,(R_2^3 - R_1^3)\, R_2\, m \cos \varphi + 6\,(R_2^2 - R_1^2)\, R_2^2\, m^2 \cos^2 \varphi \quad (16)$$

and N', N'', &c., are calculated from (16) for the different paddles by putting for φ the values φ_1, φ_2, &c., respectively.

EXAMPLE. Let seven paddles be submerged, making the following angles with the vertical: $\varphi_1 = 30° = \varphi_7$, $\varphi_2 = 20° = \varphi_6$, $\varphi_3 = 10° = \varphi_5$, $\varphi_4 = 0°$. Let $R_2 = 10$ feet, $R_1 = 8$,—therefore $m = \cdot 8$. Required the modulus of the wheel.

We have to calculate D_1, D_2, &c., from the denominator of (13), and N', N'', &c., from (16). These values substituted in (15) give the required answer.

The two paddles which make the angle 30° with the vertical, however, will contain portions which have less horizontal velocity than v or the velocity of the vessel. Hence, we must consider these paddles each as two distinct paddles, the upper portions giving a negative resistance or *drag*. To find the dividing line we have

$$R = \frac{m\, R_2}{\cos \varphi} = \frac{\cdot 8 \times 10}{\cos 30°} = 9 \cdot 238 \text{ feet.}$$

For the upper portion, therefore, $R = 9\cdot238$ takes the place of R_2, and for the lower portion, $R = 9\cdot238$ takes the place of R_1, in the formulas. The calculations are made in the following tabular form.

Angles.	1 $4(R_2^3-R_2^3)$ (Logs.)	2 $\cos^2\phi$ (Logs.)	Product of 1 and 2.	3 $12(R_2^2-R_1^2)R_2$ (Logs.)	4 $m\cos\phi$ (Logs.)	Product of 3 and 4.	$12(R_2-R_1)R_2^2m^2$	VALUES OF D.
0°	3·0350293	20·	1084·	3·3579348	9·9030900	1824·	768·	$D_4 = 28·00$.
10	"	19·9867030	1051·32	"	9·8964415	1796·29	"	$D_3 = 23·03 = D_5$.
20	"	19·9459716	957·20	"	9·8760758	1714.	"	$D_2 = 11·20 = D_6$.
30	2·3757002	19·8750612	178·14	2·6822534	9·8406206	333·33	155·99	$D_1 = -·80 = D_7$.
30	2·9276167	"	634·86	3·2108932	"	1125·94	499·42	$D_1 = 8·34 = D_7$.

To find $D_1 \cos\varphi + \&c.$

	Angles.	D (Logs.)	$\cos\phi$ (Logs.)	Products.
	0°			28·00=28.
	10	1·3622939	9·9933515	22·68×2=45·36.
	20	1·0492180	9·9729858	10·54×2=21·08.
$(D_7 + D_7)$	30	·8773713	9·9375306	6·53×2=13·06.
			∴ $D_1 \cos\phi_1 + \&c.$ =	107·50.

To find $N' + N'' + \&c.$

Angles.	$3(R_2^4-R_1^4)$	$8(R_2^3-R_1^3)R_2m$ (Logs.)	$\cos\phi$ (Logs.)	Product.	$6(R_2^2-R_1^2)R_2^2m^2$ (Logs.)	$\cos^2\phi$ (Logs.)	Product.	VALUES OF IV.
0°	10317	4·2391493	10·000000	17344·	3·8630848	20·	7296.	$N^{IV} = 269·00$.
10	"	"	9·9933515	17080·5	"	19·9867030	7076.	$2N^{III} = 625·00 = 2N^{V}$
20	"	"	9·9729858	16298·00	"	19·9459716	6442·3	$2N^{II} = 922·6 = 2N^{VI}$.
30	"	"	9·9375306	15020·4	"	19·8750612	5472.	$2N^{I} = 1537·2 = 2N^{VII}$.
								∴ $N^1 + \&c. = 3353·80$

Hence for seven paddles $M = \dfrac{m\,R_2\left[D_1 \cos\varphi + \&c.\right]}{N' + N'' + \&c.} = ·26$, *i.e.*, loss ·74

" " five " $M = ·42$, *i. e.*, loss ·58.

" " three " $M = ·66$, *i. e.*, " ·34.

Remarks on the Results.

By the result it will be seen that the loss when *seven* paddles are submerged is 78 per cent., by slip and oblique action; when *five* are submerged the loss is 58 per cent.; and when *three* are submerged the loss is 34 per cent. The great loss in the first two cases will be readily accounted for when we consider: that the *normal resistances* besides having greater velocities than the *horizontal resistances*, *increase* very rapidly as the paddles recede from the vertical,—the paddle nearest the surface having the greatest normal resistance, since it is less affected by the velocity v,—while the *horizontal resistances diminish* very rapidly at the same time; that the slip is much greater for the inner portions of the paddles than for the outer; that the upper paddles while experiencing great *normal* resistances are scarcely effective; that the vertical *velocities* are not affected by v, and therefore the vertical resistances are correspondingly greater.*

It will be observed, that if the *dip* of the wheel is diminished the slip will increase, the law of which increase can only be ascertained by experiment. It is necessary, therefore, to fall back upon experiment to ascertain the best arrangement for the paddles. We, however, see that under the best circumstances considerable power is lost by the *radial* paddle-wheel,—this loss which is almost wholly obviated in the *feathering* paddle-wheel.

Note.—These results are somewhat modified by reason of the change of position of the paddles; but the extreme positions being only 5° apart, the influence on the result is small. For any extreme case a mean of the results for the two extreme positions would give a more correct answer.

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* The above losses are increased by having the paddles wider.

For the Journal of the Franklin Institute.

General Problem of Trussed Girders. By De Volson Wood, Prof. of C. E., University of Michigan.

(Continued from Vol. xlviii, page 386.)

Before proceeding with the analysis, I wish to make an observation upon the latter part of the preceding article. I observed that Tredgold's rule was not generally reliable, but I find upon further reflection that it may be made essentially the same as Robison's, and hence may be reliable. The literal application of the rule taken in connexion with the example which he gives, will lead to the results which I indicated. But if we refer to fig. 19, Vol. xlviii, p. 385 and in it consider that the reaction of the support at A—and not the weight P—is the *straining force*, and then apply Tredgold's rule, we shall find correctly the strains on A A and A d. Now consider the strain on A d, (which is transmitted from A to d), as the *straining force*, and we shall get correct results for $d\,d$ and the second brace (tie). *So proceed to the point where the shearing stress is zero.* This method of using the rule makes it essentially the same as Robison's, but as the latter is more explicit, I should prefer it.

On page 386 there is a grammatical error caused by an omission. It should read: "The limitations to which I wished to refer, are, *we must not pass the point where the vertical shearing stress is zero, or having passed it, we must observe that the strain on the brace immediately following has a contrary sign from that determined by the rule.*"

18°. *Let the axis of* Y *intersect more than three bars.* Let us first take a simple case. Suppose that the chords are parallel, and that both the diagonal bars, as shown in figure 20, Plate II, resist strains. Take a section at g, in which Y intersects the upper and lower chords, and the inclined bars $g\,a$ and $b\,f$.

Let $F_2 =$ the strain on $g\,a$ (compressive).
$F_3 =$ " " $f\,b$ (tensive)

and the other notation as before given.

Then we find for the first members of equations (4) and (5),

$$\Sigma F \cos a = H + F_2 \sin \theta - F_3 \sin \theta - H_1$$
$$\Sigma F \cos \beta = F_2 \cos \theta + F_3 \cos \theta$$
$$\Sigma F \cos \gamma = 0$$

and couple around $Z = H_1 D + F_3 D \sin \theta$

If we also suppose that all the forces are vertical, or perpendicular to the chords; then will the values of the second members of (4) and (5) become the same as the second members of (12); hence we have the following equations:

$$\left.\begin{aligned} H + F_2 \sin \theta - F_3 \sin \theta - H_1 &= 0 \\ F_2 \cos \theta + F_3 \cos \theta &= V - \Sigma_0^x P^* \\ H_1 D + D F_3 \sin \theta &= V x_1 - \Sigma_0^x P x \end{aligned}\right\} \qquad (51)$$

Here we have four unknown quantities with but three equations; hence other conditions must be established before the problem can be solved.

It is not easy to assign the conditions which will be realized in practice. If both bars were placed side by side and inclined the same as $a\,g$; or if in their present position they were fixed with equal care, it might be safe to assume that they sustain equal strains; or $F_2 = F_3$. This condition will enable us to solve the problem. But it is difficult to fix the bars so as to realize this condition; and hence it is, that in computing such structures, or indeed compound structures generally, we assume that one of the bars sustains nearly or quite all the strain that should fall upon both, and that the other is introduced for additional security. If the bars were perfectly rigid, one or the other would be obliged to sustain all the strain; but because they are elastic, the elongation or compression of one, will tend to produce increased strains on the other. Hence, there is a constant tendency to an equality of strains on the inclined bars. Those who are familiar with the principles of bridge construction will observe that these remarks apply with equal, if not greater force to trusses which are made by combining the arch with the truss of parallel chords; of which the Burr Truss is a good example. See figure 21, Plate II. For a description of this truss see Mahan's Civil Engineering, p. 241; also Haupt on Bridge Construction.

Although such combinations are often more practical than the simple forms, yet they cannot be considered as scientific; for the strains on the several parts cannot be rigidly computed. In iron structures this is a serious objection, while in wooden ones it is not; for the cheapness of the latter material makes the size of the parts of secondary importance, and hence it is not economical to compute too closely; but the cost of the former material makes it economical to use as little as possible, having due regard to safety.

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*It will be observed that I omit the subscript of x because I deem its use no longer necessary.

Assuming, in the case before us, that $F_2 = F_3$, and equations (51) become

$$\left.\begin{array}{r} H - H_1 = 0 \\ 2F_2 \cos\theta = V - \Sigma_0^x P \\ H_1 D + DF_2 \sin\theta = V_{x_1} - \Sigma_0^x P_x \end{array}\right\} \quad . \quad . \quad (52)$$

From equations (52) we see:

1st. That the strains on the upper and lower chords equal each other.

2d. That the diagonal bars sustain the shearing stress;
and by comparing the third of (52) with the third of (40), or (45) we see,

3d. That the strain on the lower chord is less than it would be if *b f* were omitted.

If the axis of Y passes through a vertical bar without intersecting the inclined ones, θ becomes zero, and as but one bar is intersected we omit the factor 2, and (52) becomes,

$$\left.\begin{array}{r} H - H_1 = 0 \\ F_2 = V - \Sigma_0^x P \\ H\ D = V_{x_1} - \Sigma_0^x P_x \end{array}\right\} \quad . \quad . \quad (53)$$

If the axis of Y be taken just at the right of *i d*, so as to intersect only the upper and lower chords, then will $F_2 = 0$; and (52) becomes,

$$\left.\begin{array}{r} H = H_1 \\ 0 = V - \Sigma_0^x P \\ H\ D = V_{x_1} - \Sigma_0^x P_x \end{array}\right\} \quad . \quad . \quad . \quad (54)$$

We must not infer from the second of these, that $V = \Sigma_0^x P$; but rather that there is a vertical resistance in the chords equal F_2 in (53); to sustain the vertical shearing. I shall refer to this hereafter.

If the inclined bars are capable of resisting both tension and compression, the vertical bars will be unnecessary, and the truss may take the form of figure 22, Plate II. Town's Lattice is of this form, only that each piece is made to cross several which incline the opposite way, as shown in figure 23, Plate II. For a description of this lattice see Mahan's Civil Engineering, page 174, and Silliman's Journal, Volume xxxviii, 1st Series, p. 276.

To analyze it suppose that Y intersects n inclined bars which incline the same way; then will $2n$ be the total number which it intersects. We will neglect the influence of the inclined bars in relieving the strains on the chords; then by inspecting equations (52) we may write the following:

$$\left.\begin{array}{r} H = H_1 \\ 2n\, F_2 \cos\theta = V - \Sigma_0^x P \\ HD_1 = V_{x_1} - \Sigma_0^x P_x \end{array}\right\} \quad . \quad . \quad . \quad (55)$$

If the load is uniform, and extends from end to end, we have from (21) and (55),

$$\left.\begin{aligned} \mathrm{H} &= \mathrm{H}_1 \\ 2n\,\mathrm{F}_2 \cos\theta &= \tfrac{1}{2}\,w\,(\mathrm{L}-2x_1) \\ \mathrm{H}_1\mathrm{D} &= \tfrac{1}{2}\,w\,(\mathrm{L}x_1-x_1^2) \end{aligned}\right\} \quad . \quad . \quad . \quad (56)$$

For the extremities $x_1 = 0$ and we have

$$\left.\begin{aligned} 2n\,\mathrm{F}_2 \cos\theta &= \tfrac{1}{2}\,w\,\mathrm{L} = \tfrac{1}{2}\mathrm{W} \\ \mathrm{H} &= \mathrm{H}_1 = 0 \end{aligned}\right\} \quad . \quad . \quad . \quad (57)$$

For the middle section $x_1 = \frac{1}{2}\,\mathrm{L}$ and we have

$$\left.\begin{aligned} &\mathrm{H} = \mathrm{H}_1 = \tfrac{1}{8}\,w\,\mathrm{L}^2 = \tfrac{1}{8}\,\mathrm{W}\,\mathrm{L} \\ &\mathrm{F}_2 = 0 \end{aligned}\right\} \quad . \quad . \quad . \quad (58)$$

There are cases in which Y may intersect more than three bars, and yet be determinate. This is the case with figure 19, page 385, in which if Y intersects the bars less inclined, it will generally intersect five bars. It may be made to intersect three bars by using a system of oblique co-ordinates; or even, by a system of rectangular co-ordinates in which X will be inclined to the parallel chords. In this way the problem becomes determinate.

19° *Let all the bars be horizontal and resist directly as their distance from a horizontal line.*

It is generally supposed that this is the law which governs the resistance of beams when subjected to transverse strains. Several of the preceding equations give $\mathrm{H} - \mathrm{H}_1 = 0$; from which we see, that if there is tension on one side of a beam, there must be compression on the other, and that between them there will be a line of no strain. This is called the *Neutral Axis*, and a plane of such fibres is called a *Neutral Plane.*

Let A B, figure 24, Plate II, be a beam which is subjected to a transverse strain, and let us consider the effect upon any section, as C D.

Take the origin of co-ordinates at any point in the plane section, and let the axis be the same as in the first of this series of articles, only we will let Y be positive downwards. Since the fibers are parallel to X we have $a = 0$ or $180°$, $\beta = 90°$, $\gamma = 90°$, in (4) and (5) and they become,

$$\Sigma \pm \mathrm{F} = -\Sigma\,\mathrm{P}\cos a,\ 0 = -\Sigma\,\mathrm{P}\cos b,\ 0 = -\Sigma\mathrm{P}\cos c\,; \quad . \quad . (59)$$

$$0 = -\Sigma\,\mathrm{P}\,(y\cos c - z\cos b),\ \Sigma\mathrm{F}_z = -\Sigma\,\mathrm{P}\,(z\cos a - x\cos c),$$

$$\Sigma \mp \mathrm{F}y = -\Sigma\,\mathrm{P}(x\cos b - y\cos a), \quad . \quad . \quad (60)$$

If the applied forces are parallel to Y, we have $a = 90°$, $b = 0$ or $180°$, and $c = 90°$, and (59) and (60) become,

$$\Sigma \pm \mathrm{F} = 0,\ 0 = \Sigma \pm \mathrm{P},\ 0 = 0\,; \quad . \quad . \quad . \quad . \quad . \quad (61)$$

$$0 = \Sigma\,\mathrm{P}z,\ \Sigma\,\mathrm{F}z = 0,\ \Sigma\,\mathrm{F}\,y = \Sigma\,\mathrm{P}\,x \quad . \quad . \quad . \quad . \quad (62)$$

These equations are worthy of especial notice, as they contain the *theory* of resistance of beams as used in practice. The signification of each of the expressions in (61) and (62), are given in number 3°, page 232 of the preceding volume. We will now examine their interpretation.

The first, $\Sigma \pm F = 0$, is the DIRECT STRESS, and shows *that the total compressive strains on one side of the neutral axis, equal the total tensive strains on the other side.* I shall make use of this principle hereafter to find the position of the *neutral axis.*

The second shows that the sum of the upward equals the sum of the downward forces. But, as the distribution of the applied forces is arbitrary, this condition may not be established. For instance, in the figure, we suppose that there is only one force acting at the free end, and the equation becomes $0 = P$. What is the interpretation in this case? The equation evidently reduces to an absurdity; hence, we infer,

1st. *That any number of parallel fibres acting independently, and resisting only longitudinal strains, cannot sustain a force which acts perpendicular to them;* but as beams do sustain transverse forces, and as the fibres do not act independently of each other, we infer,

2d. *That in practice a beam is capable of resisting a transverse shearing stress in addition to the extension and compression of the fibres.*

The problem, then, which is stated in number 19° cannot be realized without this additional principle.

Calling this shearing stress S*s*, and we have

$$Ss = \Sigma P \quad . \quad . \quad . \qquad (63)$$

The third of (61) is simply a true equation.

The first of (62), which is the *Twisting* force, is absurd, except when the sum of the moments which tend to twist the beam in one direction equals those which twist the opposite way. If these forces are in the plane YX, then will $z = 0$, and the equation becomes $0 = 0$; but if a single force has a lever arm, z, the equation becomes $0 = Pz$. To resist this moment there is really a shearing stress, which has not been noticed in the analysis, and is called *a resistance to torsion.* In order, then, to find the true value of this resistance, we must know the laws which govern it. They are,

1st. The ultimate resistance of the most remote fibre from the neutral axis is constant:

2d. The strains upon the fibres vary directly as their distance from the neutral axis:

3d. The angle of torsion varies directly as the twisting force, and as the distance between the sections.

From these we may establish the equations for torsion.

The second of (62) shows that there is no tendency to twist about the axis of Y. It is really the *resistance* to torsion; and we have practically $\Sigma P_z = \Sigma F_z$.

The *third* shows that the sum of the moments which tend to bend the beam about the axis of z, equals the moments of the resisting forces. We will now develop this expression.

Let $a = \mathrm{OE} =$ the distance between the axis of X and the neutral plane,
$\mathrm{R} =$ the strain on the unit of fibres which is most remote from the neutral axis,
$\mathrm{R}\,dy\,dz =$ the strain on *the fibre* which is most remote from the neutral axis,
$d_1 =$ the distance of the most remote fibre from the neutral axis;
$(a + y)$ is the distance from the origin, of *any* fibre which is below the neutral axis, and
$(a - y)$ the corresponding distance above.

Then from the law of resistance which is stated in number 19°, we have

$$d_1 : a \pm y :: \mathrm{R}\,dy\,dz : \text{strain on any fibre} = \frac{\mathrm{R}}{d_1}(a \pm y)\,dy\,dz.$$

The lever arm of this strain is $a \pm y$; hence, *the moment of strain* of a single fibre is

$$\frac{\mathrm{R}}{d_1}(a \pm y)^2 dy\,dz$$

If the origin be taken upon the neutral axis, a becomes zero, and we have, after integrating so as to include the whole area,

$$\Sigma\,\mathrm{F}\,y = \frac{\mathrm{R}}{d_1}\iint y^2\,dy\,dz = \Sigma\,\mathrm{P}\,x$$

The expression, $\iint y^2\,dy\,dz$, is the moment of inertia of the section. Calling it I, and we have

$$\mathrm{I} = \iint y^2\,dy\,dz \qquad . \qquad . \qquad (64)$$

$$\frac{\mathrm{R}}{d_1}\mathrm{I} = \Sigma\,\mathrm{P}\,x \qquad . \qquad . \qquad (65)$$

Such is the relation between the strains and applied forces. If R is made equal to the strength of a unit of fibres, then (65), if applied to the *dangerous section*, i. e. the section most liable to break, will give the strength of a beam. Equation (63) must also be satisfied.

For example, suppose that a rectangular beam is supported at the ends, and sustains a weight P, at the middle. Let $b =$ the breadth, and d the depth of the beam, and l its length.

$$\text{Then } \mathrm{I} = \int_0^b \int_{-\frac{1}{2}d}^{+\frac{1}{2}d} y^2\,dy\,dz = \tfrac{1}{12}\,b\,d^3,$$

$d_1 = \frac{1}{2}d$, and for the middle section,*

$$\Sigma \mathrm{P}x = \tfrac{1}{2}\mathrm{P} \times \tfrac{1}{2}l = \tfrac{1}{4}\mathrm{P}l$$

$$\therefore \tfrac{1}{6}\,\mathrm{R}\,bd^2 = \tfrac{1}{4}\,\mathrm{P}\,l$$

The relation between the applied forces and resistances may also be found in terms of the *modulus of elasticity.* In figure 26, Plate II, let the sections C D and E H be parallel before the beam is bent, but after it is bent they will be normal to the neutral axis K L, and will meet if prolonged, in O. Let K L be indefinitely small $= d\,x$, then will O K $=$ O L $= \rho =$ the radius of curvature of the neutral axis. Prolong these radii until K M $=$ L N $= \rho$.

---

*It will be shown hereafter that according to the hypothesis which we are considering, that the neutral axis passes through the centre of gravity of the sections; hence in the rectangle $d_1 = \frac{1}{2}d$.

The modulus of elasticity may be defined to be a force which will elongate a bar to double its original length, provided the elasticity does not change. Then if E produces the elongation Q N on the fibre M Q; while R produces the elongation E F on C E; we have from the similarity of triangles, since the elongations are proportional to the strains, $\frac{E}{\rho}=\frac{R}{d_{\iota}}$ which in (65) gives

$$\frac{E\,I}{\rho}=\Sigma Px \quad . \qquad . \qquad . \qquad (66)$$

This equation is true only within the elastic limits, and hence, for small curvatures. For this case we may deduce an approximate formula which will be more convenient for use.

From Calculus, we have $\rho=\frac{(dx^2+dy^2)^{\frac{3}{2}}}{d^2y\;dx}$

$$=\frac{\left(1+\frac{dy^2}{dx^2}\right)}{d^2y}dx^2=\frac{dx^2}{d^2y}\text{ nearly.}$$

and our equation becomes,

$$E\,I\frac{d^2y}{dx^2}=\Sigma Px \quad . \qquad . \qquad . \qquad (67)$$

Out of the vast number of problems to which this equation may be applied, I will select one which yields a fruitful discussion.

EXAMPLE. *Let a prismatic beam be fixed at one end, supported at the other, and a weight* P *be applied at any point; it is required to find the equation of the neutral axis, and discuss the problem.*

One end may be fixed by being firmly imbedded in a wall, as in fig. 27, Plate II, or it may extend over a support and a weight P_{ι} applied which shall make the curve horizontal over the support, as in figure 28, Plate II, or the beam may rest on three supports, and two equal forces applied at equal distances from the middle one, as in fig. 29, Plate II. The discussion is the same in either case.

Let A B $= l =$ the length of the part considered.
V $=$ the reaction of the support at B.
$n\,l =$ A C.

Take the origin at A, and let A C be the abscissa of the point of application of the force P. There will be two curves, distinct in their nature; one A D, the other D B. We may conceive that the curve D B is caused by the force V; and A D, by V and P; or generally, as was observed in the early part of these articles, we may consider all the forces at the right (or left) of a section as producing the effect.

First consider the curve A D.

Observing that x is the abscissa of any point of the curve, and we have $(nl-x)$ for the lever arm of P, and $(l-x)$ for the lever arm of V; and by observing the proper signs for the forces, we immediately have $\Sigma Px = P(nl-x) - V(l-x)$, hence equation (67) becomes,

$$EI\frac{d^2y}{dx^2} = P(nl-x) - V(l-x) \qquad . \qquad . \qquad (68)$$

multiply by dx and integrate, and we have,

$$EI\frac{dy}{dx} = P(nlx-\tfrac{1}{2}x^2) - V(lx-\tfrac{1}{2}x^2) \qquad . \qquad . \qquad (69)$$

and again, $$EIy = P(\tfrac{1}{2}nlx^2-\tfrac{1}{6}x^3) - V(\tfrac{1}{2}lx^2-\tfrac{1}{6}x^3) \qquad . \qquad (70)$$

The constants of integration are zero; for $\frac{dy}{dx}$ and $y=0$ for $x=0$.

Let $i =$ the inclination of the curve at D, and making $x = nl$ in 69) we have,

$$\frac{dy}{dx} = \tan i = \left[\tfrac{1}{2}n^2 P - (n-\tfrac{1}{2}n^2) V\right]\frac{l^2}{EI} \qquad . \qquad (71)$$

Let $f =$ the deflection at D, and making $x = nl$ in (70) and it becomes,

$$y = f = \left[\tfrac{1}{3}n^3 P - (\tfrac{1}{2}n^2-\tfrac{1}{6}n^3) V\right]\frac{l^3}{EI} \qquad . \qquad (72)$$

Next consider the curve D B.

The origin remaining the same, we observe that x will be the abscissa of any point on D B; and the lever arm of V will be $(l-x)$; hence equation (67) becomes,

$$EI\frac{d^2y}{dx^2} = -V(l-x) \qquad . \qquad . \qquad (73)$$

Integrating this equation twice, and finding the constants by observing that $\frac{dy}{dx} = \text{tang. } i$ for $x = nl$, and $y = f$ for $x = nl$, and placing the results equal (71) and (72), and we immediately find

$$EI\frac{dy}{dx} = \tfrac{1}{2}Pn^2l^2 - (lx-\tfrac{1}{2}x^2) V \qquad . \qquad . \qquad (74)$$

$$EIy = (\tfrac{1}{2}x-\tfrac{1}{6}nl) Pn^2l^2 - (\tfrac{1}{2}lx^2-\tfrac{1}{6}x^3) V \qquad . \qquad (75)$$

To find the re-action, observe that $y = 0$ for $x = l$ in (75), and we find,

$$V = \tfrac{1}{2} P n^2 (3-n) \qquad . \qquad . \qquad (76)$$

For instance, if $n = \frac{1}{2}$, $V = \frac{5}{16} P$

if $n = 0{\cdot}5858$, $V = 0{\cdot}4145 P$

By substituting the general value of V in the preceding equations,

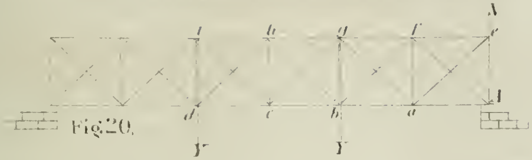

Fig.20.

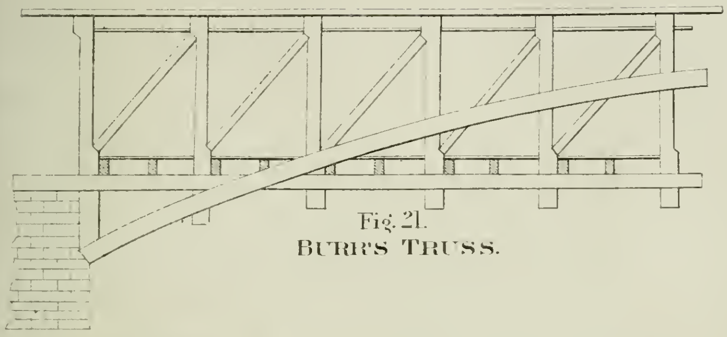

Fig. 21.
BURR'S TRUSS.

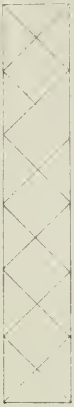

Fig. 22.

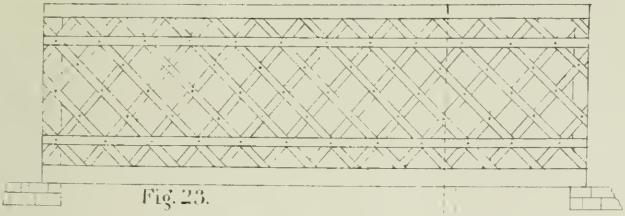

Fig. 23.
TOWNE'S TRUSS

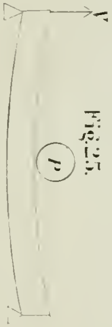

Fig. 25.

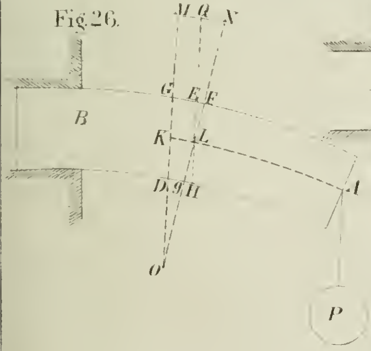

Fig.26.

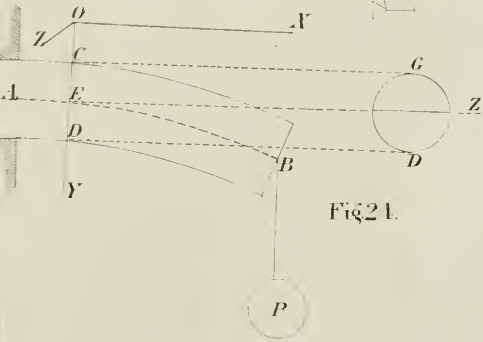

Fig.24.

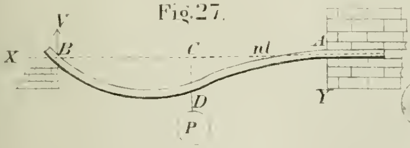

Fig.27.

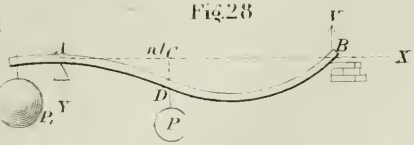

Fig.28.

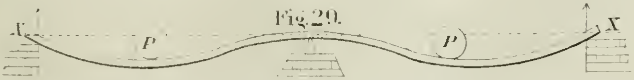

Fig.29.

they become completely determined; and we shall have for the curve A D,

$$\mathrm{E\,I}\frac{d^2y}{dx^2} = \mathrm{P}\left[nl - x - \tfrac{1}{2}n^2(3-n)(l-x)\right] \quad . \qquad (76)$$

$$\frac{dy}{dx} = \frac{\mathrm{P}}{4\mathrm{EI}}\left[4nlx - 2x^2 - n^2(3-n)(2lx - x^2)\right] \quad . \qquad (77)$$

$$y = \frac{\mathrm{P}}{12\mathrm{EI}}\left[6nlx^2 - 2x^3 - n^2(3-n)(3lx - x^3)\right] \quad . \qquad (78)$$

and for the curve D B,

$$\mathrm{E\,I}\frac{d^2y}{dx^2} = -\tfrac{1}{2}\mathrm{P}n^2(3-n)(l-x) \quad . \quad . \qquad (79)$$

$$\frac{dy}{dx} = \frac{\mathrm{P}n^2}{4\mathrm{EI}}\left[l^2 - (3-n)(2lx - x^2)\right] \quad . \qquad (80)$$

$$y = \frac{\mathrm{P}n^2}{12\mathrm{EI}}\left[(6x - 2nl)\,l^2 - (3lx^2 - x^3)(3-n)\right] \quad . \qquad (81)$$

To find the points of maximum strain. The second members of (76) and (79) give the moments of strain, and hence the greatest strain will be found by making the second members a maximum.

But in a strict mathematical sense these have no maximum. For instance, taking equation (76), we may find that value of x which will make the second member zero. From this point the function will increase indefinitely both ways—with contrary signs—as x increases or decreases. We see then, that the greatest strain on this part of the curve within the limits of the problem, will be at the fixed end and at the point of application of the force. For these points we make $x=0$, and $x=nl$ in (76) and we have for the strain at the fixed end

$$\Sigma \mathrm{P}x = \tfrac{1}{2}\mathrm{P}l\left[2n - 3n^2 + n^3\right] \quad . \quad . \qquad (82)$$

for the strain at the point of application

$$\Sigma \mathrm{P}x = \tfrac{1}{2}\mathrm{P}ln^2\left[-3 + 4n - n^2\right] \quad . \qquad (83)$$

Now considering the curve D B, and we observe from (79) that the strains increase (negatively) from the support to the point of application; hence the greatest strain is at that point, and may be found by making $x = nl$ in that equation. This will reduce it to the same as (83). *Hence* (82) *and* (83) *give the values of the greatest strains for any point of application of the force.*

Now suppose P moves along on the beam from B towards A; the strains directly under P will increase up to a certain point, and then decrease until it reaches A. *It is proposed to find the position of* P *when it produces the maximum strain*; i. e. greater than if applied at any other point. To do this we have only to find the maximum of (83) by the ordinary rules of calculus.

$$\therefore \mathrm{D} = 0 = -6n^2 + 12n^2 - 4n^3$$

$$\therefore n = 0{\cdot}634+,$$

or more than half the length of the beam from the fixed end. This value in (83) gives

$$\Sigma \mathrm{P}x = \mathrm{P}l \times 0\ 174+,$$

and in (82) gives $\Sigma \mathrm{P}x = \mathrm{P}l \times 0{\cdot}158+$.

To find where P must be applied so as to produce a maximum strain at the fixed end, we make equation (82) a maximum.

For this we find $n = 0{\cdot}422+$,
which in (82) gives $\Sigma \mathrm{P}x = \mathrm{P}l \times 0{\cdot}181+$,
and in (83) gives $\Sigma \mathrm{P}x = \mathrm{P}l \times 0{\cdot}131+$.

To find where P must be applied so that the strain at the point of application will equal that at the fixed end we make (82) equal (83) and find

$$n = \begin{cases} 1{\cdot} \\ 2{\cdot}732 \\ -0{\cdot}732 \end{cases}$$

none of which values except the first answer the conditions of the problem. But as the strains given by these equations may have contrary signs, and as we only seek numerical equality, we will place (82) equal (83) with its sign changed, and we shall find

$$n = \begin{cases} 1{\cdot} \\ 0{\cdot}5858 \\ 3{\cdot}4141 \end{cases}$$

the first two values of which are admissible.

The second value in (82) or (83) gives

$$\Sigma \mathrm{P}x = \mathrm{P}l \times 0{\cdot}171+$$

To find when P must be applied so that the curve at the point of application shall be horizontal, we make $\frac{dy}{dx} = 0$ and $x = nl$ in (77) or (80) and we find

$$n = 0{\cdot}5858+$$

which is the same value as that given above for the point for equal strain.

For $n = 0{\cdot}5858$, tang $i = 0$,
" $n > 0{\cdot}5858$, tang i is negative,
" $n < 0{\cdot}5858$, tang i is positive.

To find the corresponding deflection make $x = nl$, and $n = 0{\cdot}5858$ in (78); this gives

$$f = 0{\cdot}0098 \frac{\mathrm{P}l^3}{\mathrm{EI}}$$

But this may not give the maximum deflection. To find where P must be applied so as to produce a maximum deflection, we must first know on which side of the point of application the maximum will be. Suppose that it is between the fixed end and the point of application.

Then we find where the curve is horizontal when P is applied anywhere, by making $\frac{dy}{dx}=0$ in (77); which gives

$$x=\frac{2\,(3-n)\,n^2-4n}{(3-n)\,n^2-2};$$

and the corresponding deflection is found by substituting this value in (78). Then we find that value of n which will make this a maximum. If the maximum deflection be on the other part of the beam, we proceed in a similar way with equations (80) and (81). I have not made the reductions.

To find the point of contra flexure, make $\frac{d^2y}{dx^2}=0$ in (76) which gives

$$x=\frac{3ln^2-n^3l-2nl}{3n^2-n^3-2}$$

For instance, if $n=\frac{1}{2}$, $x=\frac{3}{11}l$

It is worthy of note that at this point the moment of strain is naught; hence there is neither elongation nor compression of the fibres, but there is a transverse shearing which may be found by equation (63). Its value at all points between the fixed end and the point of application of P is

$$\mathrm{S}s=\Sigma\mathrm{P}=\mathrm{P}-\mathrm{V}$$

Substitute the value of V, from equation (76), and we readily find that

if $n=\frac{1}{2}$, $\mathrm{S}s=\mathrm{P}-\frac{5}{16}\mathrm{P}=\frac{11}{16}\mathrm{P}=0·6875\mathrm{P}$

if $n=0·5858$, $\mathrm{S}s=0·5845\mathrm{P}$

if $n=0$, $\mathrm{S}s=\mathrm{P}$.

The *law of resistance* which we have just considered has been applied in the discussion of Tubular Girders.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On the Constitution of Sea-water at Different Depths and in Different Latitudes. By Prof. FORCHHAMMER, of Copenhagen.

From the London Chemical News, No. 263.

The number of elements hitherto found in sea-water the author stated to be thirty-one—viz: oxygen, hydrogen, nitrogen in ammonia, carbon in carbonic acid, chlorine, bromine, iodine in fuci, fluorine in combination with calcium, sulphur as sulphuric acid, phosphorus as phosphoric acid, silicium as silica, boron as boracic acid (discovered by the author in sea-water and in sea-weeds), silver in the *Pocillopora alcicornis*, copper very frequently both in animals and plants of the sea, lead very frequently in marine organisms, zinc principally in sea plants, cobal and nickel in sea plants, iron, manganese, aluminium, magnesium, calcium, strontium, and barium, the latter two as sulphates in fucoid plants, sodium, potassium. These twenty-seven elements the author himself had ascertained to occur in sea-water. The presence of the next four elements—viz: lithium, cæsium, rubidum and arsenic—has been shown by other chemists. Of these elements only a few occur in such quantity that their determination has any notable influence on the quantitative analysis of sea-water—viz: chlorine, sulphuric acid, magnesia, lime, potash, and soda. The others, as far as their existence has been determined in the sea-water itself, are found in the residue which remains after evaporation to dryness and re-dissolution of the salts in water. The author next stated that, in the water of the ocean far from the shores, the principal ingredients always occur very nearly in the same proportions. If we assume chlorine = 100, the mean proportion of the other leading constituents is as follows:—

	Mean proportion.	Maximum.	Minimum.
Sulphuric acid, . .	11·89	12·09	11·65
Lime, . . .	2·96	3·16	2·87
Magnesia, . .	11·07	11·28	10·95
All salts, . .	181·1	181·4	180.6

These proportions apply only to specimens obtained at a long distance from shores or in the open ocean. In the interior of the Baltic, for instance, the proportion of chlorine to sulphuric acid is as 100 to 14·97; to lime as 100 to 7·48; and the proportion of chlorine to all salts as 100 to 223·0. This constant proportion of the different constituents in the ocean depends evidently not upon any chemical combination and affinity between the different substances, but upon the enormous quantity of salts in the whole ocean, which renders imperceptible any difference that might otherwise arise from the different proportion in which salts are carried into the sea by rivers. It depends besides on the uniform action of the numberless organic beings inhabiting the ocean, which abstract sulphuric acid, lime, potash, and magnesia from the water, and render them insoluble. The mean quantity of solid matter in the water of the ocean generally the author found to be 34·304 per 1000.

Relative to this paper the President in his annual address made the following observations:—This communication forms a valuable contribution to a great subject—the history of the sea. It contains a full and compendious inquiry into the constituents of the water of the ocean, divided into seventeen geographical regions, each of which is studied separately from samples taken both at the surface and at various depths. An accurate view is thus gained for the first time of the sea as a whole, and conclusions of great generality are obtained. The minute analytical processes followed in several hundred analyses were so conducted as, in the opinion of competent judges, to inspire entire confidence. They confirm the presence in sea-water of the twenty-five elements already reported by other chemists, and add two others, boron and aluminium, to the number. But it is chiefly by the application of the data thus obtained to the elucidation of various geographical problems of great and general interest that we are led to recognise the full importance of this memoir. I may permit myself to notice one or two of the most remarkable of the conclusions established by it. In the Atlantic the saline ingredients in the sea-water (the samples being taken at proper distances from the land) decrease with increasing depth. This is found to hold good even to extreme depths. The existence of a polar current in the depths of the Atlantic is hence inferred, since it is a well-established fact that the equatorial seas are richer, and the polar seas poorer, in saline ingredients. The large amount of saline contents found by analysis of the water of the well-known current flowing from north-west to south-west, between Iceland and the east coast of Greenland, shows it to be, not as heretofore supposed, a polar current, but one of equatorial origin. The inference is, that it is a returning branch of the great Gulf-stream, which we have recently had reason to recognise as extending to the shores of Nova Zembla and to the north coasts of Spitzbergen, carrying to Nova Zembla the floats of the Norwegian fishermen, and to Spitzbergen the same floats, mingled with wood from Siberia. May it not be possible that the "iceless sea, teeming with animal life," described by the adventurous American explorer, Dr. Kane, as viewed from the promentory which formed the northern limit of his research, is, as he himself surmised, but an extension of the same equatorial stream which produces correspondingly abnormal effects at Spitzbergen, as well as at every other point to which its course has been traced? When physical researches shall be resumed within the circle which surrounds the Pole, this, perhaps, will be one of the earliest problems to receive solution—a solution rendered now so simple by the method of inquiry which Professor Forchhammer has made known to us. Pro. Roy. Soc. Nov. 24, 1864.

Japan Matches.

From the London Chemical News, No. 264.

Dr. Hofman, having been reminded by the Secretary that at the last meeting he had promised them an experiment, replied that after the important matter discussed that evening, and at the late hour, it was with reluctance that he addressed the Society. He had, however, heard that the Olympian gods, after diligently attending to their celestial business, were occasionally pleased to come down upon earth and to indulge in the pursuits and amusements of ordinary mortals. These Olympic traditions had been happily revived in the Chemical Society, by Mr. Septimus Piesse. The descent of the gods used to take place in a cloud of lightning. They would remember that at the conclusion of the last meeting, Mr. Septimus Piesse had furnished them with a cloud; although late in the evening, he begged permission to supply the lightning. Dr. Hofmann then exhibited some *small paper matches* which were lately given to him, and said to have been brought home from Japan. He lighted several of these matches, which burned with a small, scarcely luminous flame, a red-hot ball of glowing saline matter accumulating as the combustion proceeded. When about one-half of the match had been consumed, the glowing head began to send forth a succession of splendid sparks. The phenomenon gradually assumed the character of a brilliant scintillation very similar to that observed in burning a steel spring in oxygen, only much more delicate, the individual sparks branching out in beautiful dendritic ramifications. His first idea, Mr. Hofmann continued, had been to look for a finely divided metal in the mixture. But when examined in his laboratory, it had been found quite free from metallic constituents, and to contain carbon, sulphur and nitre, only. These constituents were present in the following proportions:—Carbon, 17·32; sulphur, 29·14; nitre, 53·64. Each match contained about 40 milligrammes of the mixture, which was folded up in fine paper. There had been no difficulty in imitating these matches. A mixture of carbon 1 (powdered wood charcoal), sulphur 1½, and nitre 3¼, produced the phenomenon in even a more striking manner. The choice of the paper was not without importance. Ordinary English tissue paper might be used. The finest matches were, however, obtained by employing genuine Japanese paper, a supply of which had been recently forwarded to him by Baron Magnus, of Berlin. In conclusion, Dr. Hofmann said that, owing to its delicacy, the phenomenon was better adapted for individual observation than for exhibition before a large audience. He had, therefore, prepared a number of these matches, which were distributed among the members of the Society.

Science in the Witness-Box.

From the London Chemical News, 265.

A writer in *Blackwood's Magazine* makes the following remarks on the examination of scientific witnesses in courts of law:—"The grandest achievement of all is a poisoning case—something that is to be two-thirds emotional and one-third scientific—where the interest vacillates between the most powerful passions and the pangs of arsenic; and the listener is alternately carried from the domestic hearth to the laboratory and back again. Now, when one is aware that the 'learned Serjeant' knows as much about chemistry as a washerwoman does of the 'wave theory,' the display of impromptu learning he makes is positively astounding. Armed with an hour's reading of Beck and Orfila, the great man comes down to court to puzzle, bewilder, and very often to confute men of real ability and acquirement; to hold them up to the world as hopelessly ignorant of all that they had devoted their lives to master; and in some cases to exhibit the very science they profess as a mass of crude disjointed facts, from which no inference could be drawn, or a safe conclusion derived. . . . A pitiable specimen is that poor man of science, pilloried up in the witness-box, and pelted by the flippant ignorance of his examiner! What a contrast between the different caution of the true knowledge, and the bold assurance, the chuckling confidence, the vain-glorious self-satisfaction, and mock triumphant delight of his questioner! Mark the practised leer, the Old Bailey grin with which he comments on something that science still regards uncertain or obscure, and hear him declare to the jury that, in the present state of medical knowledge, there is not a man in court might not be indicted for having handed the salt or the mustard to his neighbor!"

For the Journal of the Franklin Institute.

A Uniform System of Screw Threads. By Robert Briggs.

The subject of a uniform system of screw threads has recently been before the Franklin Institute, having been introduced by a paper from Mr. William Sellers, of this City, read April 21st, 1864, and having been investigated by a Committee appointed by the Institute, who have reported their conclusions at the meeting of December 15th. This report favors the adoption as the basis of uniformity, of the changes in the pitches and shapes of the threads proposed in the paper of Mr. Sellers, and does not enter so fully as might be wished into the various considerations which should influence the final decision, but is simply a confirmatory acknowledgment of the reasonings of that paper. The writer having some years since given a careful examination of the subject, would now lay before the public some of his results, not as adding much to the information of those already conversant of the points at issue, but as so fully collecting most of the considerations involved, that an undue importance shall not be given to some of them, and the partial examination lead to erroneous deductions.

On commencing the consideration of the subject, we find that custom and the practice of mechanics for many years, has established a certain number of threads per inch corresponding to each diameter of bolt or nut, and a particular form for the thread itself is so generally adopted as to bear evidence of the thoughtful design and evident purpose of many thousands of constructors and users.

The numbers of threads per inch and their form in habitual use, were examined and collated by Mr. Joseph Whitworth in 1841, and formed the subject of an excellent paper read by him at the Institution of Civil Engineers in London.

To most of the conclusions of that paper, founded as it was entirely on practice and divested of any hypothesis beyond that practice, the whole engineering world has acquiesced, and within the limits for which bolts and nuts are used as fastenings and in which the threads on the bolts have been cut by dies, and the threads within the nuts cut by taps, which limits can be stated as between one-fourth inch to two inches diameter, the number of threads designated by him, has, with one or two exceptions, been used by all subsequent makers of screws.

The most marked exception from Mr. Whitworth's table of numbers has been in the case of the $\frac{1}{2}$-inch and $\frac{5}{8}$-inch bolt threads, where it has been found that the designated numbers give so coarse a pitch to the screws, as to materially weaken the bolts by the reduction of their diameters at the roots of the threads.

The practice of different workshops has been to make the half-inch bolt, in place of the twelve threads the table calls for; thirteen, thirteen and one-half, or fourteen threads to the inch. The two latter numbers proceeding directly from three and nine, or from seven, being got readily from the ordinary change gear of screw cutting lathes, and are therefore preferable to thirteen. Similarly $\frac{5}{8}$-inch bolts are made frequently with twelve threads in place of the tabular number eleven. It will be shown further on in this discussion, that these changes have not only a practical but a theoretical basis, founded on those comparisons of proportions which can be instituted by means of graphic scales or formulas, with great propriety, before assuming as established relative parts of similar details of machinery. It is very possible that the present excellence of our screw cutting apparatus, by producing more perfect threads, would allow finer pitches than the practice of former days, even taking times so recent as 1841, were the strength of bolts under the roots of the threads and the power to be gained in the application of the screw alone considered.

But it is requisite not only to possess the ability to screw the nut up in the first instance, when the threads are, or can be clean and well oiled, but also to be able to unscrew it after the threads are clogged with dirt or rust or the oil has hardened.

The ability to perform the latter operation without risk of twisting off the bolt depends directly on the angle of inclination of the threads, or in other words, on the pitch. The frequency with which bolts are twisted off, especially the larger ones, in the effort to unscrew their nuts is an evidence that to meet this condition alone, even coarser pitches than those in general use would be desirable.

When we reflect on the quantities of bolts and nuts in existence and their general conformities, it becomes apparent that nothing but a radical improvement will justify disturbing the balance of advantages which our present dimensions have by practice attained.

Mr. Whitworth's deduction of the form to be given to the triangular threads, has however, not met with the same universal approval and compliance. On the contrary the angle of 60° appears to be that in most general use in England and to be exclusively used in the United States, in the place of the angle of 55° which the paper recommends. This angle of 60° presents one great advantage of acquirement, independent to the exact shape of the single point or chaser which cut the steel from the tap (or hob which originates the chasers) in permitting the finishing of the form of the thread, or the backing off of the tap by ordinary three cornered files.* The section of the angle of a sharp three square file is exactly that which the thread requires, as the corner, although called sharp, is really a little rounded and gives the desirable hollow at the root of the thread. We therefore see that the general practice of mechanics every where is towards a uniformity in the use of screw threads, and that very little adjustment of differences, as to number of threads to be used, or the form of thread to be adopted is necessary, and it is probable that the mutual agreement of a few leading mechanical institutions with the co-operation of some of the larger screw bolt making establishments, would meet general approval, and final entire following. It is to be noticed, however, that there is much discrepancy in the exact diameters when the nominal diameters are the same. That is, there are no standard dimensions, so that bolts and nuts of different makers and nominally of the same diameters, and having the same form of thread shall certainly interchange upon placing any nut upon any bolt.

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* It cannot with strictness be said to be impossible, it is only difficult, to back off with a file, a tap or tool for cutting either the Whitworth or Sellers form of thread. By using a three-cornered file the shape can be cut away at the back and the face of the cutting edge in front left the original outline, but the labor required would be much greater and the skill of the workman taxed to produce a satisfactory *job* to use the workshop expression.

Most of the nominal sizes in use by mechanics, whether expressed by feet or inches, or by numbers, refer to arbitrary gauges, and neither correspond to nor in any simple terms can be compared with our units of measure.

Thus gas and steam pipes of wrought iron have nominal diameters which correspond neither to the actual internal or external ones.

The diameter of wrought iron turned shafts is called that which it has been found convenient to have the merchantable round iron from which they are turned, and the thickness of sheet iron or the diameter of wires have no simple numerical relation between the numbers of the gauges and the actual dimension in inches or aliquot parts.

Similarly there is needed a set of arbitrary fixed gauges in the sizes of male and female threads so that the workman should be independent of the necessity of comparison by callipers and by rules. It not being important within a few thousandth of an inch what dimension those gauges have, only that they shall be called by their nearest diameters in sixteenths of an inch, and that they shall ensure an actual correspondance of size for all bolts and nuts of each nominal dimension.

In this regard also we are confident that standard gauges for bolts and nuts would meet approval and following.

Having thus stated the prominent facts which are open to investigation, we will now proceed to a more theoretical as well as practical examination of them.

It is evident that our attention can only be called to those bolts which are to be generally used for fastenings, for confining parts of fixed machinery or pipe flanges together, as the requirements of service for particular uses do not admit of the complete generalization of all screws.

Thus very coarse threads, which shall be either square or truncate (angular with the top and bottom corners removed) or angular in section, are demanded for valve screws, lathe screws for screw cutting or for the spindles or chucks, and generally for all running or frequently used screws; while very fine threads, very well fitted, are suitable wherever the screws are subject to jars as about hammers and on locomotive engine work. In pipes, the thickness of the material gives a limit to the coarseness of the threads and screws to run in wood, lag screws, or wood screws generally, where the strength of the two materials vary essentially call for a dissimilarity of form between the internal and external threads. In these instances any attempt to introduce a further uniformity of screw threads, than what would be comprised in a uniformity in each particular group of conditions, would be to ignore the laws of constructive mechanism.

We therefore propose to consider only the usual fastening bolts as within the scope of the present inquiry into the propriety of establishing a uniformity, but would therefore not the less endeavor to impress on all special manufacturers, as of lathes, of locomotives, of steam and gas pipes, of gas fixtures, of instruments, of wood screws, the necessity and desirability of agreeing amongst themselves as to the definite and uniform dimensions of their screws.*

We also propose to consider these bolts for fastenings only within the limits of one-fourth to two inches diameter. (The latter bolt requiring three men on a forty-eight inch lever, each man exerting a pull of 100 ℔s to pull the nut home to its maximum safe strain.)

Above two inches diameter, bolts are usually chased, and the nuts cut in a lathe and the uniformity with other bolts is made to depend so much upon the workman who fits each nut to its bolt that it is impracticable to ask, if not impossible to ensure it.†

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* Note.—The manufacturers of wrought iron steam and gas pipes, have already established and agreed to the sizes and proportions of their pipes and threads, which are shown in the accompanying table from Morris, Tasker & Co.'s List.

Table *of Standard Dimensions of Wrought Iron Welded Tube.*

Nominal Diameter.	Actual Outside Diameter.	Thickness.	Actual Inside Diameter.	Internal Circumference.	External Circumference.	Length of Pipe per sq. foot of inside surface.	Length of Pipe per sq. foot of outside surface.	Internal Area.	External Area.	Length of Pipe containing one cubic foot.	Weight per foot of length.	No. of threads per inch of screw.
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Feet.	Feet.	Ins.	Ins.	Feet.	℔s.	
⅛	0·405	0·068	0·270	0·848	1·272	14·15	9·44	0·0572	0·129	2500.	0·243	27
¼	0·54	0·088	0·364	1·144	1·696	10·50	7·075	0·1041	0·229	1385.	0·422	18
⅜	0·675	0·091	0·494	1·552	2·121	7·67	5·657	0·1916	0·358	751·5	0.561	18
½	0·84	0·109	0·623	1·957	2·652	6·13	4·502	0·3048	0·554	472·4	0·845	14
¾	1 05	0·113	0·824	2·589	3·299	4·635	3·637	0·5333	0·866	270·	1·126	14
1	1·315	0·134	1·048	3·292	4·134	3·679	2·903	0·8627	1·357	166·9	1·670	11½
1¼	1·66	0·140	1·380	4·335	5·215	2·768	2·301	1·496	2·164	96·25	2·258	11½
1½	1·9	0·145	1·611	5·061	5·969	2·371	2·01	2·038	2·835	70 65	2·694	11½
2	2·375	0 154	2·067	6 494	7·461	1·848	1·611	3·355	4·430	42·36	3 667	11½
2½	2·875	0·204	2·468	7·754	9·032	1·547	1·328	4·783	6·491	30·11	5·773	8
3	3·5	0·217	3·067	9·636	10·996	1·245	1·091	7·388	9·621	19·49	7·547	8
3½	4·0	0·226	3·548	11·146	12·566	1·077	0·955	9·887	12·566	14·56	9·055	8
4	4·5	0 237	4·026	12·648	14·137	0·949	0·849	12·730	15·904	11·31	10·728	8
4½	5·	0·247	4·508	14·153	15·708	0·848	0·765	15·939	19·635	9·03	12·492	8
5	5·563	0·259	5·045	15·849	17·475	0·757	0·629	19·990	24·299	7·20	14·564	8
6	6·625	0·280	6·065	19·054	20·813	0·63	0.577	28·889	34·471	4·98	18·767	8
7	7·625	0·301	7·023	22·063	23·954	0·544	0·505	38·737	45·663	3·72	23·410	8
8	8·625	0·322	7·982	25·076	27·096	0·478	0·444	50·039	58·426	2·88	28·348	8
9	9·688	0·344	9·001	28·277	30·433	0·425	0·394	63·633	73·715	2·26	34·077	8
10	10·75	0·366	10·019	31·475	33·772	0·381	0·355	78·838	90·762	1·80	40·641	8

Taper of threads, 1 to 32 on each side.

In estimating the effective steam heating or boiler surface of tubes, the surface in contact with the air or gases of combustion (whether internal or external to the tubes) is to be taken.

For heating liquids by steam or transferring heat from one liquid or one gas to another, the mean of the internal and external surfaces is to be taken.

An enlarged section of a pipe thread showing the form and the taper of the screw is given Fig. 3, Plate III.

† Note.—In this country there has been in use the past few years some machines for cutting the screws upon bolts, based upon the scroll screw plate of Mr. Whitworth, so that the cutting dies can be removed after the bolt is threaded without backing out the bolt, a process which endangers the cutting edges of the dies either from friction or from the liability of a piece of swarf jamming on the tooth.

Besides, there are certainly no reasons founded on former established habit which will justify the use of any thread on a bolt so large as two-and-one-fourth inches diameter or above, which does not answer the exact condition of the special requirement of use for the bolt.

The mechanic who is about to fix upon the proportions of anything similar to other things in use, refers either directly or by memory to a comparison of dimensions with what he, or others may have before done. Thus he would reason, if ten threads to an inch are needed or are used for three-fourth inch bolts, then some less number would be suited to an inch and-a-half bolt, and as he would consider the quantity of iron to be removed as well as the diameters of the respective bolts, he would decide the number of threads on the latter should not be in inverse ratio of the diameters, but rather less, and he might fix upon six threads for the proper number.

Proceeding further for other sizes he would infer that seven-eighths inch bolts should be coarser threaded than three-fourths inch, one inch bolts than seven-eighths, &c., and he would intuitively construct a table which should embrace all the sizes between three-fourths and one-and-a-half inch bolts, and perhaps above and below those dimensions, the whole being based upon, and having its correctness dependent on the assumption as regards the three-fourths inch bolt first, and the derived assumption as regards the one-and-a-half inch bolt last. The workman would thus by a species of mechanical perception, have established a series of proportional dimensions and when the minds

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These cutter dies are usually made on the principle patented in this country about 1848, by P. W. Gates, and then introduced by him.

(Mr. Gates' patent seems to have been anticipated by one to A. Lamont in 1830, but it is certain his method was not brought into use until he advocated it in person.)

The cutters are placed in the scroll plate with the planes of their cutting faces radial to the centre of the plate and are tapped or chased out parallel a little larger than the screw which is to be cut. The entering side of the plate is then coned out so as to obliterate the first thread and remove the points of three or four more.

Upon setting in the cutters to the size of the screw, it will be found that the backs of the teeth are relieved, and if the proper allowance for this relief has been made in the enlarged size of the original hole, they will (when sharpened to the right cutting form on the face) act precisely like well made lathe tools.

Machines with die plates as described have been successfully introduced into many workshops, and especially have come into use in the Railroad shops for cutting the larger bolts required in bridge construction where lathe cut screws have hitherto been used. Although the whole number of bolts reckoned by numbers wanted for these purposes is very small, yet it is cheaper to fit up a set of dies and taps to thread them, than to cut them in the lathe, beside admitting the cutting of long bolts without welding. The question has, therefore, arisen as to what should be the best form of thread and the pitch of the threads for bolts of this description, say from 2¼ inches to 3½ inches diameter.

In this case the question is divested of the average practice of mechanics in both regards and should be decided on its own merits.

To quote from Mr. Sellers: "The necessity of guarding the edge of the thread from accidental injury becomes more and more apparent as the size of the bolt is increased. Considering the whole case on the basis of our own paper, as well as on its merits, we think that bolts for bridge construction, might by agreement of Railway Engineers, as a special case, have a form approximating to Mr. Whitworth, of 60° sides with rounded top and hollow at bottom of thread.

of many have been brought to the consideration of the same point in the same way, these proportional dimensions will be found expressible in some algebraical form of the general case.

Thus supposing $P =$ the pitch of the thread, or the distance from the point of one thread to the point of another.

$d =$ the outside or nominal diameter of the bolt,

and $N =$ the number of threads,

we have at once $N = \frac{1}{P}$ or the reciprocal of P and we find the following formula to express as nearly as the fractional character of the exact results can be expected to, the proposed and proper numbers of threads to an inch to be used for screw bolts.

First, Mr. Whitworth's table is very nearly expressed by

$$P = 0{\cdot}1075\,d - 0{\cdot}0075\,d^2 + 0{\cdot}024 \text{ inch.}$$

Second, Mr. Sellers proposes

$$P = 0{\cdot}24\sqrt{d + 0{\cdot}625} - 0{\cdot}175 \text{ inch.*}$$

Third, the writer uses within limits

$$P = 0{\cdot}096\,d + 0{\cdot}026.$$

The Table on page 117, shows the results of these three formulas.

The formula which so closely expresses the values of Mr. Whitworth's tables cannot be extended beyond his upper limit. At $7\frac{1}{6}$ ins. diameter the curve of the values of P reaches its maximum, and the values then decrease with the increase of the diameters.

The formula of Mr. Sellers, gives a curve whose final form would be $0{\cdot}24\sqrt{d}$ where d is so large that the constants can be neglected and consequently is not open to the palpable defect of Mr. Whitworth's formula, but the pitches becoming proportionally finer for the large sizes the question of ease of unscrewing is to be investigated. It is difficult to discover on what grounds the second power, or the square root of d should enter into these equations at all.

The formula of the writer alone has any value (beyond describing arbitrary and undesired curves) as its simplicity admits of its application to other purposes, especially in calculating the general case of the useful effect or strength of the system of screw bolts as modes of fastening or in sustaining loads. This formula could be extended to all practical dimensions and although the pitches for the larger bolts above 3 inches appear out of proportion when compared with Mr. Whitworth's tables, it can be demonstrated Mr. Whitworth's are dis-

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* NOTE.—Mr. Sellers gives

$\Delta =$ diameter of screws,

$x =$ pitch of screws,

$a =$ constant 2·909

$c =$ divisor 16·64

$d =$ number of sixteenths plus ten in Δ,

$$x = \frac{\sqrt{d} - a}{c} = \frac{\sqrt{16\,\Delta + 10} - 2{\cdot}909}{16{\cdot}64}$$

$$\therefore x = 0{\cdot}24\sqrt{\Delta + 0{\cdot}625} - 0{\cdot}175$$

proportionately fine when the nut is to be removed from the rusted bolt.

It is to be noticed that all the formula agree in showing the discrepancy in the pitch assumed by Mr. Whitworth for the half-inch bolt, and that admitting his other tabular values to have the correct basis of average practice, this one was a general departure from the common law.

Tabular results of the three formulas.

Diameters of Bolt.	MR. WHITWORTH.			MR. SELLERS.		WRITER.	
	Exact Numbers.	Nearest Aliquot.	Table.	Exact Numbers.	Nearest Aliquot.	Exact Numbers.	Nearest Aliquot.
$\frac{1}{4}$	19·80	20	20	20.	20	20.	20
$\frac{5}{16}$	17·57	18	18	17·85	18	17·84	18
$\frac{3}{8}$	15·79	16	16	15·38	16	16·13	16
$\frac{7}{16}$	14·37	14	14	13·90	14	14·7	15
$\frac{1}{2}$	13·17	13	12	12·50	13	13·5	14
$\frac{9}{16}$	12·18	12		11·49	12	12·5	12
$\frac{5}{8}$	11·32	11	11	10·75	11	11·63	12
$\frac{3}{4}$	9·95	10	10	9·36	10	10·2	10
$\frac{7}{8}$	8·90	9	9	8·40	9	9·09	9
1	8·06	8	8	7·63	8	8·2	8
$1\frac{1}{8}$	7·39	7	7	6·99	7	7·47	7
$1\frac{1}{4}$	6·82	7	7	6·49	7	6·85	7
$1\frac{3}{8}$	6·35	6	6	6·10	6	6·34	6
$1\frac{1}{2}$	5·94	6	6	5·71	6	5·88	6
$1\frac{5}{8}$	5·59	6	5	5·40	$5\frac{1}{2}$	5·49	$5\frac{1}{2}$
$1\frac{3}{4}$	5·29	5	5	5·13	5	5·16	5
$1\frac{7}{8}$	5·02	5	$4\frac{1}{2}$	4·90	5	4·84	5
2	4·78	$4\frac{1}{2}$	$4\frac{1}{2}$	4·67	$4\frac{1}{2}$	4·59	$4\frac{1}{2}$
$2\frac{1}{4}$	4·39	$4\frac{1}{2}$	4	4·31	$4\frac{1}{2}$	4·13	4
$2\frac{1}{2}$	4·06	4	4	4·00	4	3·76	$3\frac{3}{4}$
$2\frac{3}{4}$	3·73	4	$3\frac{1}{2}$	3 76	4	3·45	$3\frac{1}{2}$
3	3·58	$3\frac{1}{2}$	$3\frac{1}{2}$	3·54	$3\frac{1}{2}$	3·18	$3\frac{1}{4}$
$3\frac{1}{4}$	3·39	$3\frac{1}{2}$	$3\frac{1}{4}$	3·35	$3\frac{1}{2}$	2·86	3
$3\frac{1}{2}$	3·24	$3\frac{1}{4}$	$3\frac{1}{4}$	3·19	$3\frac{1}{4}$	2·77	$2\frac{3}{4}$
$3\frac{3}{4}$	3·11	3	3	3·04	3		
4	2·99	3	3	2·92	3		
$4\frac{1}{4}$	2·90	$2\frac{7}{8}$	$2\frac{7}{8}$	2·81	$2\frac{7}{8}$		
$4\frac{1}{2}$	2·81	$2\frac{7}{8}$	$2\frac{7}{8}$	2·71	$2\frac{3}{4}$		
$4\frac{3}{4}$	2·73	$2\frac{3}{4}$	$2\frac{3}{4}$	2·61	$2\frac{5}{8}$		
5	2·68	$2\frac{3}{4}$	$2\frac{3}{4}$	2·53	$2\frac{1}{2}$		
$5\frac{1}{4}$	2·62	$2\frac{5}{8}$	$2\frac{5}{8}$	2·45	$2\frac{1}{2}$		
$5\frac{1}{2}$	2·57	$2\frac{5}{8}$	$2\frac{5}{8}$	2·38	$2\frac{3}{8}$		
$5\frac{3}{4}$	2·54	$2\frac{1}{2}$	$2\frac{1}{2}$	2·31	$2\frac{3}{8}$		
6	2·51	$2\frac{1}{2}$	$2\frac{1}{2}$	2·25	$2\frac{1}{4}$		

Fig. 1, Plate III, shows a graphic delineation of the curves and lines expressed by the formulas.

A bolt is subject to two strains, tension or the strain in direction of the length of the bolt, occasioned by the load it carries or the force it expends in holding the parts it confines together: and torsion, which is the force in the plane of rotation tangential to the cylindrical body of the bolt and is composed of two distinct applications of power, first, that which proceeds from the component of the load on the inclined screw surface, which is either positive or negative as the screw is employed to raise or lower the load; and secondly, that which comes from the frictional resistance of the moving screw surfaces under the loads imposed upon them.

The capacity of the bolt to resist tensional strain, is of course, dependent on the area of the section at the root of the teeth, and the shallower the teeth, either from using fine pitches or by having a great angle, at the tops and bottoms or by rounding or truncating the points, the larger that area.

Ordinary wrought iron, such as is generally used in bolts can be stated to be reliable for maximum load under 20,000 ℔s per square inch, and the absolute tensile strength of any bolt may be safely estimated on that basis.

It is well to remark at this place that the rounding of the root of the thread adds to the tensile strength of the bolt should it be strained to its utmost, and come to its safe working strain of one-third the ultimate one.

Thus a piece of iron of the following shape, say, ½-inch in diameter at the smallest part, and 1 inch in diameter at the central enlargement will, from the conditions of elasticity of solid bodies, be impaired in tensile or torsive strength by the abrupt enlargement, one-fifth to one-fourth of that which a plain bar of one-half inch diameter would possess. The torsional strain which is exerted on the bolt in screwing up, when the component of force expended in producing tension is positive, equals the tensional strain (that is, the bolt is as likely to twist off as to tear asunder) when the value of the co-efficient of friction has certain definite amounts.

We will not attempt to enter into this calculation, but will only give results, trusting that the evident probability of these results may suffice in this place and taking the following special cases:

Nominal diameters,	½,	¾,	1,	1½,	2,	3, ins.
Value of frictional co-efficient when torsion equals tension,	0·32,	0·33½,	0·34,	0·35,	0·35½,	0·36,

showing a slight increase of torsional strength in these cases for the larger bolts. And generally that in screwing up bolts there is no danger of twisting them off, unless, the frictional resistance exceeds one-third the insistant load.

Similar calculations have given for unscrewing where the component of force expended in relieving the tension is negative, a similar table of results, only that the differences of values for frictional coefficient, which would twist off the bolt are reversed, and the larger resistance must be taken for the smaller bolt. And the general result in this last case is that, about 38 per cent. must be taken for the average value of the frictional co-efficient to twist off the bolt.

The frictional resistance encountered in turning a nut can hardly be called that of motion, as each successful wrench-hold finds the surfaces of contact in a state of rest, but in screwing up the nut, the condition of these surfaces is much more favorable than in unscrewing after a lapse of time under load, and this value of 38 per cent. is often reached on rusted, and not oiled screws. The larger bolts not only have greater values to their frictional co-efficients from the less angle made by the thread with the plane of rotation relatively with the smaller bolts; but are generally more closely fitted by their nuts, so that their nuts are not so readily started by a few blows when fixed by rust. Coarser pitches give at once the possibility of looser fitting nuts and better angle of thread-line for relief.

The next point for discussion is the form of the threads. If bolts were made of uniformly sound iron (not to say of the highest tensile strength), and if nuts were so well fitted that the bearing should always extend over the whole surface of the threads in place of being a contact on but some portion of that surface at the tips, (which occurs when the threads have not the same angular form or when the diameter of the bolt is smaller than is proper for the calibre of the nut); such a thing as a stripped screw (with the usually adopted height of nut) would be unknown, whether the threads were triangular or Whitworth formed, or truncated and independent entirely on the fineness of the threads employed.

But in practice, both unsound iron and badly fitted nuts, not only occur but are to be taken into account in the view we now institute.

The merchantable round iron from which bolts are made is often shelly and loose on the external skin, caused either by the piling of the fagot from which it is rolled, by the closing down of fins formed in the process of rolling, or by more serious defects in the iron itself; and the punched nut is liable to have its fibre destroyed by the operation of cold punching, with badly made or dull punches and dies, (the parallel requirement of the hole compelling the use of punches the same size with the die being unsuited, however sharp, to cutting the iron out) so that it is a normal condition of the usual bolts and nuts of the workshop, and the market, to be made of poor material. Beside all this, the requirements of ease of fixing, demands a shaking fit, that no little dirt or rust or indentation will prevent the use of the bolt in the trench, on the boiler, over the furnace, or at the work-bench.

And this extreme latitude of imperfections is not to be taken as interfering with the proper accuracy of the best workshop practice. Supposing all the above mentioned allowances are made, they will not prevent the use of the best iron and the forged or hot pressed nut, neither will they preclude the bolt which shall be made the full size of the standard being accurately and properly fitted by the nut which shall be tapped out to the smallest dimension which the standard bolt will admit. After these remarks it is easy to see that the finally adopted form must be that which balances many conditions against others and is not a matter of calculation, but for deliberation. Thus the finer the pitch, (the form of threads being assumed,) the stronger the bolt, but with the fine pitches we are deprived of the requisite looseness of fitting and the threads being cut in the external laminæ of iron are likely to be imperfect and weak. If, after what we have before said, we are prepared to coincide with universal practice and assume the pitches, as given by our formula, then the less depth the threads have, the stronger are the bolts, but with the shallow threads the bearing surfaces are reduced, or if angular, cause excessive frictional resistances. Then there is the question of convenience in making tools for cutting bolts and nuts, and the question of ease with which such tools will operate in threading, and the question of durability of the tools in service. We will not pursue this abstract view further. Making machinery *a priori* is a palpable absurdity. In Mechanics the performance always precedes the reason for it, and sometimes taxes the reasoner beyond his ability. It has been assumed that the form of the teeth of bolt threads under discussion shall have the outline of angle of 60°, more or less rounded at the point and hollowed at the root. The angular form gives the junction at the root of the tooth with the body of the bolt or nut the largest section possible, while the action of the load upon the inclined surface affords a capacity to resist stripping, proportionate to the angle of inclination. (Strictly speaking, proportional to the tangent of the angle of inclination.)

In wooden screws and nuts, the angle of 90° for the sides of the thread has been found to present that resistance at which they rarely strip, although the fibre of the wood presents the most favorable direction for splitting.

With a slight round or truncation at the points, they are made very loose to allow the wood to swell or shrink and in the case of hand or bench screws of the cabinet or pattern maker are very durable in service.

Screws about a trip hammer when tapped into cast iron require fine pitches to keep them from jarring out, and the same section of thread as wood screws have to obtain the same advantages over the more friable material. For mathematical instruments and for screwing in thin plates, screws sometimes have the angle of 45° especially when steel is the substance of both bolt and nut.*

The deep tooth given by the angle of 60°, permits much looseness of fit, allows imperfections of thread, either from the wear of tools or from defects of iron, and presents a large bearing surface for the load on the bolt; of course all these are at the expense of the strength of the bolt, but for example, if a three-fourths inch bolt is not strong enough to perform a certain duty it is better to use a seven-eighths bolt, and thus preserve the advantages enumerated.

In the cases of tie rods for roof or bridge construction this condition of enlargement of rods to obtain requisite strength under the roots of the threads does not exist at all. All sound or economical engineering demands that the ends of such rods shall be upset at welding heat and swedged to such diameter as shall allow the root of the thread when cut to be larger than the body of the rod elsewhere, both to secure an excess of tensile strength and also to gain something to resist the cross strain which generally affects such rods from an unfair bearing of the nut on its seat, besides the reduction of weight and cost of the entire rod. Consequently the pitch and form of threads for such screws should be exactly what is wanted, and are to be determined independent from those adapted to ordinary purposes.

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*Any person wishing to study this subject should, before concluding, examine Holtzapffel's Mechanical Manipulation, Vol. II.

There is no form of cutting edge so easily produced or maintained in shape as that of a simple triangle and the form of tooth we have described, is too well known to all mechanics to need here in a paper addressed to them any further statement or argument in favor of its advantages.

Recurring to the alternative forms proposed, Mr. Whitworth's form is not attainable by any ready or convenient process of the workman.

By means of master taps, hobs and chasers which are all perishable as standards of form, at great expense of gauges as samples, it might be feasible to introduce and perpetuate it.

The head of the best reputed workshop in Great Britain, himself one of the most esteemed writers on mechanical subjects, has been twenty-three years endeavoring to introduce this decription of thread with such success as only to bear evidence of the general reluctance to change, even for the attainment of uniformity. Mr. Sellers' form has some advantages over that of Mr. Whitworth, first, that a gauge which he describes places it in the power of any workman to originate the exact shape of each size; secondly, that when the taps and dies are new and unworn, considerable additional bearing surface on the threads is gained by the substitution of corners for the rounded ends at the points and roots of the threads; and thirdly, by some considerable additional strength which the reduction of depth of threads may give to the bolts themselves. The latter advantage being in common to both the proposed forms, as contrasted with the usual V form.

Considering these points in order, first, the gauge proposed by Mr. Sellers is almost as valuable for originating Mr. Whitworth's thread as his own, as it gives a definite length for the extremities of the threads hardly attainable otherwise. It is certainly a very ingenious and satisfactory method of accomplishing its purpose. Secondly, the gain of bearing surface: this would disappear rapidly with the wearing away of the corners of the teeth, so that the final appearance, which might result, if after use, some person should collate the average form of thread made by taps and dies originally with sharp cornered truncations would hardly differ in any discernible respect from Mr. Whitworth's result.

The deterioration of the V form of 60° is towards a correspondence with Mr. Whitworth's result, and a completely worn out tooth, has a shape approximating to two semicircles with a tangential contact of the curves, the ends of the tooth being rounded off, and the internal corner hollowed out until what there is left of the side is nearly vertical to the bolt. Thirdly, the gain of strength from the shallowness of the threads equal, this point has been before met in the general discussion, by pointing out the advisability of enlarging the bolt rather than of reducing the thread surface.

As a conclusion therefore we take the form of thread as shown in an enlarged outline, see fig. 2, Plate III, as appearing to have so extensive sanction in use, that much more weighty reasons should be found before we would willingly recommend any change.

Were either the alternative shapes, that endeavored to be introduced by Mr. Whitworth, or that proposed by Mr. Sellers, in general use the question could be entertained as to the propriety of revising the form in favor of that we now have, and notwithstanding the confusion such a change would entail we think many would consent to the effort. As it is on the principle of holding fast to that which is good, we cordially recommend a uniformity of gauges and pitches, together with our usual form of V thread, as follows: The form has, when new, the depth of 0·8, the pitch in place of 0·866 which would be the dimension were the corners made absolutely sharp. This depth is that which the best workshop practice for well fitted bolts has adopted, but the custom of those who make bolts as an article of sale, has been to make a further allowance on the corners, so that the depth of common threads is about 0·75 the pitch of the threads. The commonly made bolt will always run in the well made nut, but the well made bolt will only run in the usual nut, when that nut is made slightly larger than a perfect fit. The real enlargement needed, however, is but the three thousandth part of an inch of diameter in a three-fourth inch bolt, and is within the limits of looseness required for merchantable bolts. So that the well made screws will operate in all cases in practice with good common ones, if the original gauges correspond, except as regard the extreme angular depths.

Proceeding to the examination of the dimensions of the nuts. The form of the nut is to be determined by the convenience of turning, and the general advantages of four or six sides can be conceded without argument. Nuts with five, eight or ten sides, spanner nuts of various arrangements of pins or polls are required for special purposes, but four or six sides alone give convenience of griping or proper surfaces to grip upon.

The height of the nut is to be established by the following considerations. First, what height is required for wear, and to meet the frictional resistance on the surface of the threads? Second, by the convenient wrench-hold for turning. Third, by what is needed for strength of threads to resist stripping. The load on the surface of the threads of a well-fitted bolt or nut of the section before proposed, is from 25 to 20 per cent. of the tensional strain on the section of bolt, below the root of the threads, and it varies but little for whatever value of friction co-efficient we adopt whether screwing or unscrewing. That this load is excessive, we show by special example.

Suppose the height to be assumed at equal the diameter of the bolt, and take a three-fourths bolt and nut for instance. A workman exerting a force of sixty pounds on a twelve inch long lever, (or wrench,) will raise fifty-five hundred pounds, (at least) and the insistant load on the thread surface becomes about eleven hundred pounds, the tension on the iron of the bolt will then be 20,000 ℔s per square inch, and the insistant load on the thread surfaces over four thousand ℔s per square inch.

It is one of the most striking corroborations of the laws of frictional resistances that subject to constant use under loads to this amount, (as our statement of the length of lever and force applied to it will make evident to any mechanic,) nuts are turned by forces proportionate to the loads upon them.

Nothing but the universality of the proportion stated, would warrant the deduction that it is sufficient.

Founded on practice, we take the height of nut equal the diameter of the bolt as regards frictional requirement, but we consider it the least practical height admissible.*

The wrench-hold also is taken as sufficient on the same basis of habit that being the only guide for the settlement of this requirement.

As for the strength needed to resist stripping, making allowance for loss of root connexion with the body of the bolt occasioned by the hollow at the bottom, it still remains that the whole height of nut (of sound iron) demanded to resist detrusion, is but one-fourth the outside diameter of the bolt and if the fit is very imperfect and loose, so that each thread has the nature of a beam supported at one end and loaded one-half way out, one-half the diameter becomes abundant.

All the conditions are consequently fulfilled if the first is answered. And we conclude H should equal d.

The diameter for the nuts measured across the inscribed circle is fixed first, at that which will resist the oblique strain on the threads tending to split the nut, making all allowances for imperfections of forgings and the strain of tapping; and second, by the area of surface of the under side of the nut, which carries the load; and third, by that which gives the facets of the nut sufficient size for wrench hold.

It will suffice here to say that calculations have been made to show the value of the strain tending to split the nut, that it varies between one-half to two inch nuts, from one-tenth to one-seventh the tensional strain on the section below the root of the thread of bolts, and that the consideration of the two last points only is needed; these considerations giving sufficient strength to resist tapping strains which is not susceptible of estimation.

We will assume as in the case of the height of the nut that the inscribed diameter of the nut shall be expressed by a formula as below.

$$D = 1\tfrac{1}{2}\, d + \tfrac{1}{8} = 1{\cdot}5 + d\ 0{\cdot}125$$

and our calculations give the following results :†

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*This great weight on the surface of the threads justifies the practice of making nuts much higher when they are to be frequently turned.

†The bearing of the nut is taken to be the area of the inscribed diameter of the nut, minus the area of the hole in the flange, or surface on which it rests, which hole with some allowance for clearance, is assumed to have the diameter of

$$= 1{\cdot}03\, d + 0{\cdot}03.$$

let K = tensional strain on iron of bolt per square inch.

K_{III} = load on the under surface of nut " "

These for the following sizes of bolts,

diameters	$\frac{1}{4}$,	$\frac{1}{2}$,	$\frac{3}{4}$,	1,	$1\frac{1}{2}$,	2,
$\frac{K_{111}}{K}$,	0·17,	0·31,	0·39,	0·43,	0·47,	0·50

That is, for a two inch bolt the load on the surface of the nut is one-half the tension on the bolt so that when the bolt is tightened to its utmost safe strain of 20,000 lbs per square inch, the load on the nut surface will be 10·000 lbs per square inch. Bolts certainly do work and work well under these insistant loads on the surfaces of friction, but nothing but use would justify carrying the laws of friction to any such extreme points, and the figures evidently show the necessity of finished nut surfaces and of washers on the larger sizes.

The dimensions of the facets of the nuts are found to be ample when the sizes of nuts are those which the assumed formula gives.

We conclude on $D = 1{\cdot}5d + 0{\cdot}125$

when D equals inscribed diameter of nut whether square or hexagon.

The dimension of the heads are governed by the same considerations which we have stated for the nuts, except that the requirement for height is not dependent on frictional resistance on the surface of the threads and the demand for convenient wrench-hold has fixed on

$$H, = 0{\cdot}8d \text{ as ample}$$

when $H,$ = height of head.

The diameters are more conveniently the same, as that of the nuts, so that the same wrenches fit, if occasion demands.

Proceeding on our assumption that the depth of the threads shall equal $0{\cdot}8P$, we obtain for the diameter of the root of the thread of any bolt $= d_2 = d - 2\,(0{\cdot}8P)$, for best workshop bolts, or,

$d_2 = d - 1\,(07{\cdot}5\ P)$, for good merchantable bolts, this would be the diameter of the hole in a nut to be tapped out if it were not found necessary to allow for the upsetting of the iron towards the points of the threads which results in cutting away the opposite sides at the same time. If it were attempted to run a tap into a hole the same diameter as the body of the tap, the iron would clog upon the tool and present a great resistance to driving it, while the thread would almost invariably strip.

In cast iron the thread would certainly crumble away, and in wrought iron it would only be preserved by the stretching of the thread, as a burr on the side opposite that in which the tap is entered. The amount of the allowance necessary is dependent on the dulness of the tap, or the care and skill with which the teeth have been *backed off* so as to cut like lathe tools.

Making the proper allowances for these considerations we have for the diameter of hole in untapped nuts $d_h = d - 2\,(0{\cdot}7P) + 0{\cdot}01$ for ordinary use, and $d_h = d - 2\,(0{\cdot}75P) + 0{\cdot}005$ for very well made and sharp taps and best fitted nuts.

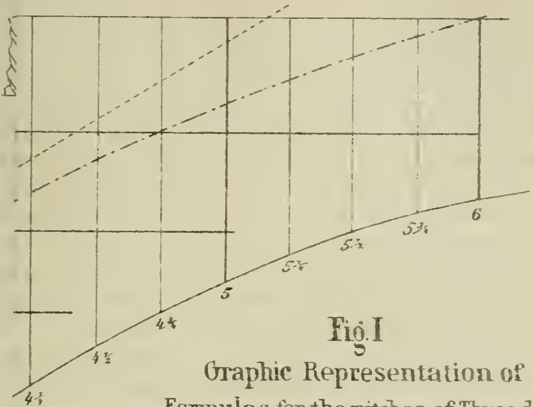


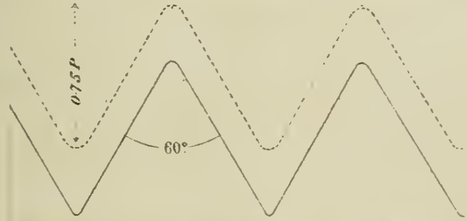
Fig. I

Graphic Representation of
Formulas for the pitches of Threads of
Screw Bolts.

horizontal scale 1¼ vertical scale 13¼ times full size.

Fi

ines show the usual best form of Threads of merchantable bolts



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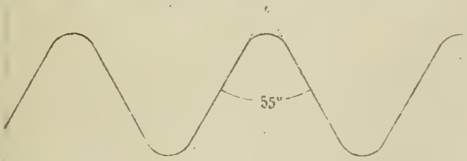
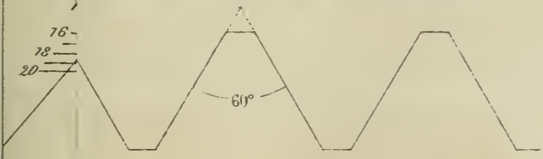


f Thread introduced Mr. Whitworth.



of Thread proposed by Mr. Sellers.

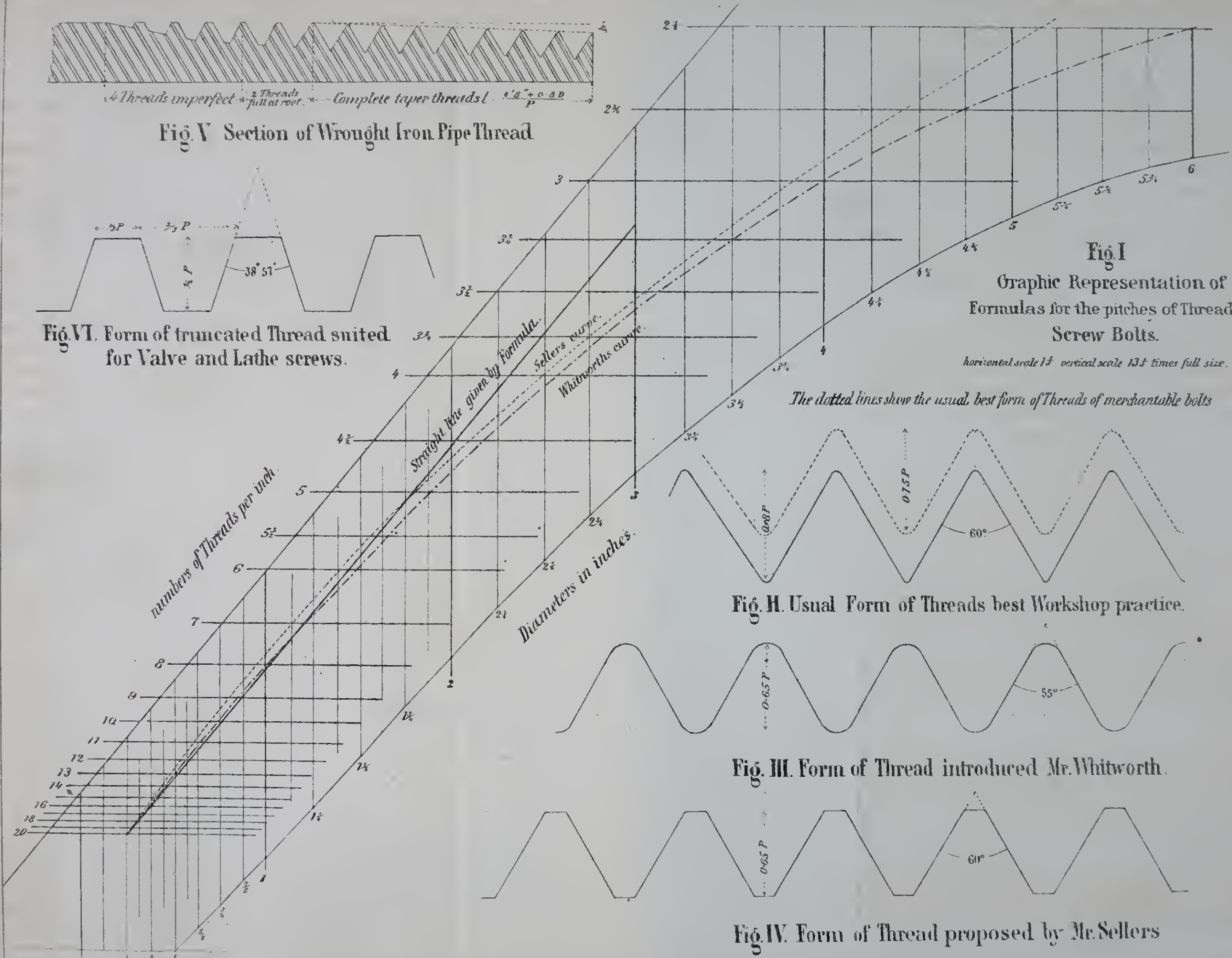


Fig. V Section of Wrought Iron Pipe Thread

Fig. VI. Form of truncated Thread suited for Valve and Lathe screws.

Fig. I
Graphic Representation of
Formulas for the pitches of Threads of
Screw Bolts.
horizontal scale 1½ vertical scale 13½ times full size.

The dotted lines show the usual best form of Threads of merchantable bolts

Fig. II. Usual Form of Threads best Workshop practice.

Fig. III. Form of Thread introduced Mr. Whitworth.

Fig. IV. Form of Thread proposed by Mr. Sellers

"We recapitulate the formulas relative to the system of screw threads.

1st. The number of threads per inch $\text{N} = \frac{1}{\text{P}} = \frac{1}{0{\cdot}096d + 0{\cdot}026}$

2d. The depth of the threads for best finished screws $= \text{T} = 0{\cdot}8\text{P}^{\circ}$.
" " " " merchantable " $= \text{T} = 0{\cdot}75\text{P}^{\circ}$.

3d. The inscribed diameter of nut or head whether square or six sided, $\text{D}_\text{n} = 15d + 0{\cdot}125$.

4th. The height of the nut, $\text{H} = d$

5th. The height of the head, $\text{H} = 0{\cdot}8d$

6th. The diameter of the hole in the nuts before tapping out $= d_\text{h}$

The following table gives the results of the first of these formulas.

The following table gives the results of our discussion :

Diameter of Bolt.	Number of Threads.	Diameter of Nut.	Height of Nut.	Diameter of holes in nuts, allowing for upsetting of threads.	Height of Heads.
$\frac{1}{4}$	20	$\frac{1}{2}$	$\frac{1}{4}$	0·190	0·2
$\frac{5}{16}$	18	$\frac{9}{16}$	$\frac{5}{16}$	0·255	0·25
$\frac{3}{8}$	16	$1\frac{1}{16}$	$\frac{3}{8}$	0·297	0·30
$\frac{7}{16}$	15	$\frac{3}{4}$	$\frac{7}{16}$	0·355	0·35
$\frac{1}{2}$	14	$\frac{7}{8}$	$\frac{1}{2}$	0·410	0·4
$\frac{9}{16}$	12	$\frac{15}{16}$	$\frac{9}{16}$	0·452	0·45
$\frac{5}{8}$	12	$1\frac{1}{61}$	$\frac{5}{8}$	0·518	0·5
$\frac{3}{4}$	10	$1\frac{1}{4}$	$\frac{3}{4}$	0·62	0·6
$\frac{7}{8}$	9	$1\frac{7}{16}$	$\frac{7}{8}$	0·729	0·7
1	8	$1\frac{5}{8}$	1	0·84	0·8
$1\frac{1}{8}$	7	$1\frac{3}{4}$	$1\frac{1}{8}$	0·935	0·9
$1\frac{1}{4}$	7	2	$1\frac{1}{4}$	1·060	1·0
$1\frac{3}{8}$	6	$2\frac{3}{16}$	$1\frac{3}{8}$	1·152	1·1
$1\frac{1}{2}$	6	$2\frac{3}{8}$	$1\frac{1}{2}$	1·277	1·2
$1\frac{5}{8}$	6	$2\frac{9}{16}$	$1\frac{5}{8}$	1·402	1·3
$1\frac{3}{4}$	5	$2\frac{3}{4}$	$1\frac{3}{4}$	1·48	1·4
$1\frac{7}{8}$	5	$2\frac{15}{16}$	$1\frac{7}{8}$	1·605	1·5
2	$4\frac{1}{2}$	$3\frac{1}{8}$	2	1·7	1·6

Lime Abroad and at Home.

From the London Builder, No. 1140.

My experience being somewhat at variance with the statements put forward under this and a like heading in the last two numbers of the *Builder*, it may, perhaps, be worth giving. The mode described of making mortar in Southern Italy has been practised in this country, time, immemorial. A pit is dug in the ground, may-be 30 ins. deep, large enough to contain perhaps a one or two horse-load of lime. Water is put into the pit, the lime is shoveled in gradually, while at the same time it is stirred to and fro with a mortar fork, and so on till the whole is dissolved to the consistency of thick cream; the stones of course settle at the bottom, and when the lime subsides the water is run off. In a short time a firm bed of putty is ready to make mortar of, then, or at any time within six months, if the lime-pit be protected from rain and sun. Of course a hard film or protective coating forms itself on the surface; under this the lime remains fresh and mellow to almost an indefinite length of time. Of mortar made with lime so prepared, I can testify from twenty years experience to its hard-setting and durable qualities. It has never occurred to me to test exactly the qualities of this as compared with any other mortar prepared from fresh-slaked lime; but I may observe that the practice of making mortar from lime-putty, and in the rough-and-ready way above described, seems to be dictated by necessity rather than choice. It prevails chiefly in the country where, from the great distance it has sometimes to be carted, it would be impracticable, for ordinary building purposes, to have fresh-slaked lime on every occasion. W. M.

An Account of Apparatus and Processes for the Chemical and Photometrical Testing of Illuminating Gas. By Prof. W. B. Rogers.

From the London Athenæum, Oct., 1864.

The instruments and methods described in this communication are those adopted in the gas inspection lately organized by Prof. Rogers, for the State of Massachusetts; comprising the measurement as well as testing of gas. Connected with the former of these objects, an account was given of the adjustments of the standing measure for gauging gasholders,—of a universal clamp for meter-connexions,—and of an appendage combining a delicate thermometer and pressure gauge for the inlet and outlet of the meter, and by which the rate of delivery is accurately adjusted. For chemical testing, the eudiometer, consisting of a graduating tube, with cylindrical enlargement, is permanently enclosed in a wider tube full of water, which maintains the temperature nearly uniform. The mouth of the graduated tube is furnished with a hollow ground stopper, for holding the several liquid absorbents used in the successive experiments. With this apparatus it is easy to determine the percentage of carbonic acid, of illuminating hydrocarbons, of oxygen, and of carbonic oxide; after which the hydrogen and light carburetted hydrogen are ascertained by explosion, by means of an instrument consisting mainly of two glass tubes, united below by a long loop of rubber-tube, being a modification of Frankland's apparatus. For determining the sulphur, an improved arrangement is used, in which the stream of water supplying the Liebig's condenser is made to convey a stream of air, mingled with ammonia, into the condensing tube some inches above the flame of the burning gas. To secure a larger and more constant unit of illumination than the candle commonly used, a lamp burning kerasine, with a flat wick, is employed, in which, by means of a bridge of platinum wire, the flame may be maintained of constant size, and giving a light equal to about seven candles. This is supported on a balance of peculiar construction, giving the consumption during the experiment. Prof. Rogers had found that even the small amount of carbonic acid which in some gas-works is allowed to remain in the gas produces a sensible reduction of the light. This effect varying with the strength of the illuminating gas, was found to range from 3 to nearly 5 per cent. of the illuminating power for each per cent. of the impurity: 58 per cent. of carbonic acid, although it did not prevent combustion, made the flame so dim as to be without effect on the photometer.

On Boring Rocks.

From the London Mechanics' Magazine, December, 1864.

Sir:—The enormous outlay which attends the opening and working of mines in districts where the strata are, as in Cornwall, of an exceedingly hard nature, is due mainly to the slow progress which can be made in sinking shafts, or driving levels or headings through such refractory rocks. Thus £ 60 per fathom is not an unusual price for sinking a shaft in hard Cornish stone; and even at this immense cost the progress made is very small. In solid limestone rock a shaft 9 feet in diameter can be sunk for £ 7 per fathom, and at the rate of ten fathoms per month; but a shaft in hard capal or roskear stone costs £ 60 per fathom, and perhaps not one fathom per month can be sunk.

In each case, the labor is mainly accomplished by boring holes in the rock, and firing them with charges of powder, the explosion of which bursts, and breaks up the rock.

Now in limestone these holes can be rapidly bored, because limestone is considerably softer than good hardened steel, and therefore the steel borer keeps its edge a long time, and cuts the rock keenly and quickly. But capal or roskear stone is nearly and often quite as hard as the best hardened cast steel; hence the edge of the borer is soon worn or beaten up, and in place of cutting the stone keenly, it merely bruises it away by degrees, making slow progress through it, and to enable even this to be done, the edge of the borer bit has to be made very thick and obtuse, and in a form the least calculated to penetrate rapidly. In boring a hole 8 inches in hard veinstone, upwards of 200 borer bits have had to be re-set by the smith, and the cost of each re-setting or tempering is fairly stated at about threepence for each bit, taking labor, loss of time, &c., &c., into consideration. Now, if a steel can be produced which, when hardened, will be as much harder than capal or roskear stone as the best hardened steel at present made is harder than limestone, then by the aid of this steel shafts may be sunk and levels driven in the hardest ground as rapidly and as economically as can at present be effected into ordinary limestone rock.

Such a steel can be produced, and I invite the attention of mining engineers, contractors, mine owners, and shareholders in mines to this all-important subject. They need only test the steel according to my directions to convince themselves that what I have advanced can be borne out in practice. When used for boring ordinary rocks, this steel is all but imperishable in its edge. Two hundred feet have been bored with a single borer in limestone rock without the bit requiring to be fresh dressed and tempered.

Apart from any interest of my own as an inventor, this matter is one of the deepest national importance; and the adoption of the steel in question in the Cornish mines would enable the miner's interest there to set foreign competition at defiance, and numbers of mines now barely paying cost would at once spring up into dividend mines, whilst a multitude of other mines now abandoned from the depression of the prices of copper and tin would immediately be brought into active operation.

R. Mushet.

Cheltenham, Dec. 26, 1864.

Trial of a New Machine for getting Coal.

From the London Mechanics' Magazine, December, 1864.

On Wednesday last a coal cutting machine, on an entirely new principle, the invention of Messrs. Lock and Warrington, colliery owners, Kippax, and Messrs. Carrett and Marshall, engineers, Leeds, was tried at the Kippax Colliery, near Leeds, in the presence of a number of colliery owners and mining engineers, including Mr. Embleton, Mr. Morton, Mr. Pope, Mr. Rayner, Mr. Parker, Mr. Pickersgill, and other gentlemen. The trial in every respect was perfectly successful, and every gentleman present expressed his satisfaction at the manner the machine performed its work. The coal-cutting machines which have been tried recently in other districts have been worked by compressed air, and on the principle of the pick motion. This machine is, however, worked by water pressure, at 150 ℔s to an inch, conveyed in $1\frac{1}{2}$ inch wrought iron pipes, from a small engine fixed near the bottom of the pit. The trial was made in the Allerton seam of coal, which is five feet six inches thick, but contains a layer of dirt three inches thick at the height of 20 inches from the floor, which separates the best and second seams of coal. The machine was mounted on four wheels, and traverse on the corf tramways. The "holing" or "baring," which is the hardest and most laborious part of the collier's work, was done remarkably well, in one even straight line, and to a uniform depth, at once passing over. The cutters were fixed in a slotting bar, worked with a steady longitudinal reciprocating motion at a slight angle, which ripped out the whole of the partition of dirt to a depth of three feet three inches. The apparatus being entirely *self-acting in all its operations*, it propelled itself forward, secured itself dead fast between the floor and roof, whilst the cutters were in operation, and again released itself with the return stroke. The machine is strong, and not at all complicated, and is likely to work with durability. It is beautifully arranged in its various movements, and works with such precision and exactness that any one might almost fancy it was endowed with intelligence. One man is all that is required to attend to it, and he has nothing to do but to set it in motion and stop it when required. The machine worked on Wednesday two hours forty-nine minutes, and excavated the dirt out three inches thick and three feet three inches under for a length of twenty-two yards and two feet, and liberated from the solid bed of coal forty-four tons. The average cost of "baring" by hand labor at the same colliery is 8d. per ton; but the principal saving is in the economical working of the coal, without cutting such a large proportion into slack as is done by hand labor. The pressure of water can be increased to any required extent and its quantity needs only to be enough to fill the circuit of the pipes, the same incompressible fluid thus being used over and over again to convey the power any required distance from the source of power to the coal seam to be operated upon. The miners have named this new labor saver the "iron-man," and from his self-acting and industrious powers, it is probable he will never become tired. Messrs. Lock and Warrington are so well satisfied with the advantages of getting coal by machinery that we understand they are making more machines in order to take all their coal worked by them.—*Leeds Mercury*, Nov. 21, 1864.

On a New Formula for Calculating the Initial Pressure of Steam.

By Mr. R. A. Peacock.

From the London Athenæum, Oct., 1864.

Some years ago the author had occasion to attempt to calculate the probable pressure of steam at the highest known temperatures, and found, amongst other things, that between the pressures of 25 ℔s per square inch and 300 ℔s to the square inch, the latter being the highest pressure to which trustworthy experiments had been carried, the law of increase was approximately: That the temperature of high-pressure steam of, say, 25 ℔s to the square inch and upwards, increases as the $4\frac{1}{2}$ root of the pressure; and that, conversely, the pressure of the steam of, say, 25 ℔s to the square inch and upwards, increases as the $4\frac{1}{2}$ power of the temperature. At lower pressures than about 25 ℔s per square inch, a different law prevails. As it is necessary to verify the new formula by comparison with some well known formulas and experiments, the author has attempted to do so in a very voluminous table, and graphically in a very carefully executed diagram. What is to be gathered from these is, that the new formula agrees with Dr. Fairbairn's experiments, from about 40 ℔s to 60 ℔s and very nearly with Regnault's, between 220 ℔s and 336 ℔s.

Experiments on the use of Petroleum as a Fuel for Propelling Steam Machinery.

From the London Mechanics' Magazine, December, 1864.

An elementary course of experiments was commenced last week in the factory department of Woolwich dockyard, with a view of testing the capacity of petroleum to supersede coal and other fuel on shipboard, and also in propelling steam machinery in the factories. The method adopted is the patented invention of Mr. C. J. Richardson, an engineer residing at Kensington. The plan under trial is simply to burn the petroleum through a porous material, which is placed in an iron chamber, dipped into a water vessel also of iron. The oil admitted into the chamber soddens the porous material, and rises by a sort of capillary attraction. The surface then catches fire and burns rapidly, as long as the oil is supplied. The effect of the flame is so great that with the small apparatus, which is only two feet superficial area and affixed to a boiler, the oil on Saturday was utilized so as to be equal for steam purposes to five tons of coals. A third advantage is obtained by the employment of the petroleum—namely, that no stokers are needed, and the boilers can be supplied with several fires one above another. The small grate used in the experiments was placed under a boiler of 17-horse power, and in two hours it raised the steam to 10 fbs pressure. The only objection seems to be the fear of explosive qualities, but these Mr. Richardson states he is prepared to guard against effectually.

Substitutes for Cranes and Hodmen in Paris.

From the Journal of the Society of Arts, No. 630.

The *Builder* states, that "some of the contractors re-building the demolished houses, and running up quickly new mansions, have hit upon an ingenious way of raising materials to the top of the scaffold. As the head of water at the Vilette is enough to command any of the houses in Paris, they have simply a pipe turned on from the main up to the top of the intended structure, and by that means can fill a bucket or large tub, which in descending draws up a plateau on which the materials are placed. The water, being turned into mortar, and otherwise made use of afterwards below, is not lost. Some of the materials are also hoisted by Lenoir's machine (by gas); there is one at work at the Rond Pont de Corcelles, close to the Avenue de Ternes. It seems to be, by timing a weight ascending a certain height, about $2\frac{1}{2}$-horse power. The absence of a boiler in these engines is a strong argument in favor of employing them where steady slight power is required. At all events, if they are not endowed with the abundant force of a steam engine, yet in towns and confined streets, where only a moderate source of power is required to act in a small compass, noiselessly and without nuisance, we have seen that the required mechanical effect can be accomplished without risk of explosion, and consequent damage and loss of life, either to owners or their neighbors. That is something at all events."

Use of Petroleum as Steam Fuel in place of Coal. By B. H. Paul.

From the London Chemical News, No. 263.

Some months ago considerable interest was excited by the announcement that very remarkable results had been obtained in America by the application of petroleum as fuel for the boilers of steam vessels, and so much importance was attached to the subject, that a Commission was appointed by the Government of the Northern States to inquire into this application of petroleum.

The report published by the Commission, as the result of their labors, was calculated rather to excite curiosity than to afford satisfactory information, and they have not, so far as I am aware, made public any further data which would afford a means of arriving at an opinion on the subject.

The proposal to use petroleum as steam fuel in ships became, almost of course, a subject of consideration in this country, and an idea prevailed that this invention might possibly supersede in importance all the recent improvements connected with the naval or mercantile marine. It was anticipated that not only naval warfare, but even navigation itself, might be completely revolutionized by this invention. It was reasonable enough that a project put forward with such pretension as was the case in respect to the use of petroleum as fuel for steam vessels, should be considered in a country where every improvement relating to steam navigation is of high importance; but it is surprising that no one should have disabused the public mind of the erroneous impressions produced by the statements as to the use of petroleum as fuel; for to any one conversant with the composition and characters of petroleum, as compared with coal, this proposed application of it was obviously absurd.

Lately little has been heard of this project until some days ago a notice appeared in the *Times*, under the head of "Naval and Military Intelligence," that experiments are being conducted at the Woolwich Dockyard, with the view of testing the capability of petroleum to supersede coal and other fuel on ship-board, &c. In this notice it was stated that the oil was so utilized "as to be equal for steam purposes to five tons of coal!" How much of the oil was equal to five tons of coal was not stated, but it may be fairly supposed that any one unacquainted with the subject would infer that one ton of oil was meant.

Now, what are really the facts of the case as to the comparative advantages of petroleum and coal as fuel?

In the first place, one of the chief alleged advantages of petroleum over coal, was that it would lie in a small compass and make less demand upon space and tonnage than coal does. Since with petroleum in the place of coal, two-thirds of the space now required for fuel in a steam vessel would be saved, steamships might keep at sea three times as long as at present. Then, coal depots would be unnecessary for steam packets on the longest lines of ocean navigation; and since no stokers would be needed in using petroleum, a whole army of employees might be dispensed with.

Now, the specific gravity of coal is from 1·24 or 1·44 to 1·6, while that of petroleum is from 0·800 to 0·850, consequently the weight of a cubic foot of these materials would be, respectively, about as follows:—

	lbs.	lbs.	lbs.
Coal, . .	77·4	90	100
Petroleum, .		50	53

But, since petroleum, being liquid, lies in a more compact manner than coal; in estimating the spaces occupied by these materials, allowance should be made for the interstices or empty spaces between the lumps of coal. Taking this as amounting to one-third of the whole bulk of a heap of coals—which is a liberal allowance—the contents of a cubic foot would be as follows:—

	lbs.	lbs.	lbs.
Coal, . .	52	60	70
Petroleum, .	50	53	—

So that the spaces occupied by equal weights of coal and petroleum would be about as 1 is to 1·2 or 1·4.

Then the relative heating power of equal weights of coal and petroleum would depend upon their respective chemical composition, which may be compared as follows for 100 parts:—

	Coal.	Petroleum.
Carbon, . .	83	85
Hydrogen, . .	5	15
Ash, &c., .		
	100	100

Accordingly, the relative heating power of equal weights of coal and of petroleum would be in the following ratio:—

	Coal.	Petroleum.
Calorific power, . .	1·02	1·50

And the spaces occupied by quantities of petroleum and of coal, having equal heating power, would be in the ratio of 1 to 1·16.

This difference in favor of petroleum is in itself too small to admit of any advantage being gained in regard of stowage, and it is more than doubtful whether there be any other advantageous difference between petroleum and coal for fuel.

It must also be considered how far the difference between the prices of petroleum and coal would have the effect of neutralizing the above or any other advantage to be gained by the use of petroleum as fuel. The price of petroleum varies from 15*l.* to 20*l.* per ton, while that of coal used for steam vessels is under 1*l.* per ton at any part of the British coast, and even at the coaling stations in the East it does not exceed 2*l.* 10s. to 3*l.* 10s. per ton.

These considerations alone appear to me to decide the question as to the practicability of using petroleum as steam fuel under any possible circumstances, for even in the case most favorable for the comparison of petroleum with coal, the cost of equal quantities of heat produced from these materials would be in the ratio of 15*l.* to 4*l.*

In addition to this, the highly inflammable nature of petroleum must be considered. Its storage on board a ship would require the use of air-tight vessels, and even then there might be considerable risk of the production of explosive mixtures of the petroleum vapor and air. But what would be the condition of a vessel of war provided with petroleum as fuel, if a shot penetrated the vessel containing the petroleum, and allowed it to escape in proximity to the boiler fires?

Taking all these circumstances into consideration, I think there cannot be any doubt as to the entire fallacy of supposing that petroleum can be substituted for coal as fuel; and though this conclusion is sufficiently evident from the data I have adopted as to price, &c., it must also be remembered that the tendency is rather to a rise in the price of this commodity than otherwise.

On the Chemical History and Application of Gun-cotton. By Prof. Abel, F.R.S., Chemist to the War Department.

From the London Chemical News, No. 235.

Continued from page 44.

Many attempts have been made from time to time to diminish the rapidity of explosion of gun-cotton, but the only one which has been attended by any success is that which, in General von Lenk's hands, has led to the development of a system of mechanical arrangement of gun-cotton as ingenious and simple as it is effective. By manufacturing the cotton into yarn of different thickness and degrees of compactness or firmness of twist, *before* its conversion into gun-cotton, this material is at once obtained in forms which not only burn with great regularity and much less rapidity, when used in the original condition, than the loose gun-cotton wool, but which also when employed in the form of reels, wound more or less compactly, or, by being converted into plaits or hollow ropes, may be made to burn gradually in a manner similar to gunpowder, or to flash into flame instantaneously, exerting an explosive action which very far exceeds that of the latter. The modifications in the nature and degree of explosive force exerted by gun-cotton which are essential for its application to military and industrial purposes as a substitute for powder, are therefore arrived at by means of very simple variations in the mechanical condition of the material. Thus, to obtain the gradual action essential for the employment of gun-cotton in cannon, cartridges are made up of coarse yarn, which is wound firmly around a hollow cylinder of wood, the dimensions of which are regulated by the size of the gun-chamber and the weight of the charge used; the best result is obtained by so arranging the latter that the cartridge entirely fills the space allotted to the charge in the gun. Similarly, small-arm cartridges are made of cylindrical plaits of fine yarn or thread, which are fitted compactly in layers, one over the other, upon a small cylinder or spindle of wood. In both of these arrangements the combustion of the charge can proceed only from the exterior surfaces towards the interior of the cartridge. On the other hand, the charges for shells, in which the most rapid explosion is most effective, and the priming for quick matches which are intended for firing several charges simultaneously and almost immediately upon the application of flame, consist of cylindrical, hollow, and moderately compact plaits (similar to lamp-wicks), made of gun-cotton thread or very fine yarn. These plaits are produced in pieces of any length, and, when employed as quick-match, are compactly enclosed in cases of water-proof canvass or other similar materials. The charges to be used in mines, in which the most destructive effects are aimed at, consist of pieces of very firmly twisted rope, with a hollow case along the centre, the number of strands of which it is composed varying with the size of the charge to be used. For quarrying and blasting purposes suitable lengths of the rope are employed singly; for military operations (demolition of works, &c.), it is packed into moderately stout cases of sheet metal. In these hollow ropes and plaits of gun-cotton, the flame produced by the burning of that portion to which heat is applied, penetrates at once to the interior and into the interstices of the charge; and hence the entire mass of gun-cotton is converted into gas and vapor with almost instantaneous rapidity. A striking illustration of the very opposite effects which can be produced by very simple modifications in the mechanical arrangement of the gun-cotton is afforded by the following experiment: If two or three strands of gun-cotton yarn be very loosely twisted together and inserted into a tube of glass or other material, in which they fit so loosely as to be readily drawn backwards and forwards, upon applying heat to a projecting portion at one end of the tube, the gun-cotton thus arranged will explode with great violence, completely pulverizing the tube, if it be of glass, and the combustion will take place with such almost instantaneous rapidity that small portions of unburnt gun-cotton will actually be scattered by the explosion. But when two or more strands of the same gun-cotton yarn be tightly twisted, singly in the first instance, then made up into a firm cord solid throughout, and enclosed in a glass tube, or some other description of case, into which the cord fits very tightly, if a protruding end of the gun-cotton be inflamed, the cord will burn with moderate rapidity until the fire reaches the opening of the case, and then the combustion will pass over from the ordinary kind to a form which can only be described as smouldering; the lighted extremity of the gun-cotton simply glows within the case, while a steady jet of flame (furnished by the combustible gases evolved from the gun-cotton) continues to burn at the open extremity of the case until the contents of the latter are consumed. The gun-cotton not only burns extremely slowly under these conditions, but also with the greatest regularity; so that the rate of combustion of a given length of the enclosed cord may be accurately timed. The rapidity of combustion of gun-cotton arranged in this form may be regulated by the number of strands in a cord and the degree of their compactness; and it is by this new modification of General von Lenk's system of arranging gun-cotton that the lecturer has succeeded in applying this material to the production of slow-matches and time-fuses —uses for which it had not previously been found suitable.

Reference has just been made to inflammable gases evolved by gun-cotton while it undergoes a very slow combustion. The composition of gun-cotton renders it self-evident that under any circumstances the explosion of this substance must be accompanied by the production of a very considerable proportion of carbonic oxide. The large body of flame always observed when gun-cotton is ignited under ordinary circumstances, is principally due to the combustion of carbonic oxide, and probably also of small quantities of carbo-hydrogen compounds, which, together with minute suspended particles of the mineral matter contained in the gun-cotton, give to the flame its brightness. If a tuft of gun-cotton be ignited in a capacious and somewhat deep vessel, the flame actually resulting from the burning of the tuft may be distinctly seen surrounded by a large body of flame, produced by the burning gases, which continues apparent for a very appreciable time after the disappearance of the flash of flame furnished by the explosion of the gun-cotton. If similar tufts be ignited in atmospheres of hydrogen, nitrogen, carbonic acid, coal gas, &c., the combustion of the gun-cotton is only accompanied by a very small and pale flame, of instantaneous duration. Similarly, if gun-cotton be ignited in a vessel which has been previously exhausted to any rate one-half the ordinary atmospheric pressure, the proportion of air, and therefore of oxygen, present when the gun-cotton is ignited, does not suffice to effect the combustion of any large proportion of the inflammable gases generated, and hence the explosion of the gun-cotton is attended only by a small pale flame. If, however, the vessel be filled with oxygen, and then exhausted to an equal or even a lower degree, it is filled with a flame of dazzling brightness directly the ignition of the gun-cotton is effected.

The one modification, just referred to, of the phenomena which attend the ignition of gun-cotton in a rarefied atmosphere is not the only result observed in experiments of this kind. Various curious effects may be obtained, their nature being determined by the degree of rarefaction of the atmosphere; the mechanical condition of the gun-cotton; its position with reference to the source of heat employed; and other variable elements in the experiments. A brief account of some of the principal of these phenomena may not be without interest.

In the experiment with a tuft of gun-cotton in rarefied air, spoken of just now, a perceptible interval is observed between the first application of heat (by passage of a voltaic current through a platinum wire enclosed in the tuft) and the first appearance of ignition of the gun-cotton; moreover, the pale flame, observed when the latter does burn, is of very perceptibly longer duration than that of the bright flash which attends the explosion of gun-cotton in air under ordinary conditions. If instead of using the gun-cotton in the form of a tuft, a short piece of the gun-cotton yarn be employed in the experiment, and laid on a support so that it rests upon the wire by which it is to be ignited, the pale flame of the burning gun-cotton will travel along towards the two extremities of the piece of yarn with a degree of slowness corresponding to the extent of rarefaction of the atmosphere. These results are in perfect accordance with the observation first made by Quartermaster Mitchell, afterwards fully examined into by Frankland, and recently amplified by Dufour, that the rate of burning of time-fuses is influenced by the altitude at which they are burned, or, in other words, by the degree of pressure of the atmosphere, the combustion being proportionately slow with every decrement of pressure of the air. When the platinum wire is first raised to a red heat in the centre of the tuft of gun-cotton, enclosed in a highly rarefied atmosphere, the products resulting from the decomposition of that portion of the material which is in close contact with the wire, immediately distribute themselves through the rarefied space, conveying away and rendering latent by their expansion the heat furnished by the platinum-wire and that which results from the chemical change. The increase of pressure within the confined space, by the generation of the gases and vapors, on the one hand, and, on the other hand, the effect of the heated gases, which escape, upon the particle of gun-cotton through which they permeate, result, in the course of time, in the ignition of the mass; but, even then, the gun-cotton burns only slowly, because, in consequence of the rapidity with which the resulting gases and vapors escape and expand, much of the heat essential for the maintenance of the combustion is at once conveyed away. The latter result is strikingly exemplified by the experiment in which gun-cotton-yarn is substituted for the tuft of corded cotton; indeed, if the atmosphere be very highly rarefied (to 0·6 in inches of mercury), and a sufficient length of the gun-cotton-yarn (4 or 5 inches) be employed in the experiment, the burning of the material induced by the heated wire will proceed so slowly that the heat resulting from the chemical change will he conveyed away from the burning surface, by the gases generated, much more rapidly than it is developed; so that the gun-cotton will actually become extinguished when only a small portion of it has been burned.

A very similar result is obtained if gunpowder, either in the form of grains or of one large mass, is exposed to the action of an incandescent platinum wire imbedded in it, the pressure of the atmosphere in the apparatus in which the experiment is made being reduced to between 0·6 and 2 in inches of mercury. The portion of gunpowder contiguous to the heated wire will fuse, vapors of sulphur will be evolved in the first instance, and subsequently the charcoal will be oxidized by the nitre, bubbles of gas escaping from the fused mass. The vapors and gases thus generated convey away rapidly the heat provided by the wire and developed by the chemical action; and at the same time, the change which the gunpowder undergoes diminishes its explosive character, so that its partial ignition or explosion will only be effected after the lapse of several minutes, and if it be in the form of grains, the explosion of the particles contiguous to the wire will have the effect of scattering the remainder without igniting it.

The great reduction in the rapidity of combustion of gun-cotton is not the only result observed when small quantities of that substance are exposed to heat under diminished atmospheric pressure. In the most highly rarefied atmospheres (from 0·5 to 1 inch) the only indication afforded of the burning of the gun-cotton is the appearance of a beautiful green glow, like a phosphorescence, immediately surrounding that part which is undergoing decomposition. When the pressure of the atmosphere is slightly increased, a faint yellow lambent flame appears beyond the green glow, at a short distance from the point of decomposition; and in proportion as the atmosphere is less rarefied, this pale yellow flame increases in volume, while the green phosphorescence becomes less and less apparent, until it seems to be completely obliterated. Lastly, when the pressure of the atmosphere is comparatively great (=25 or 26 in inches of mercury) the gun-cotton burns with the ordinary bright flame, though less rapidly of course, than it does under normal conditions of atmospheric pressure. There is no doubt that this bright flame is due to an almost instantaneous secondary combustion (in the oxygen supplied by the air in the apparatus) of the inflammable gases evolved by the decomposition. On the other hand, the production of the small pale flame observed when gun-cotton is burned in more highly rarefied air, or in atmospheres of gases which cannot supply oxygen for combustion, is most probably due to the generation of a mixture of gases (by the change which gun-cotton undergoes under these conditions), which contains not only combustible bodies, such as carbonic oxide, but also a proportion of oxidizing gases (protoxide of nitrogen, or even oxygen); such as a mixture, having self-combustible properties, will receive sufficient heat from the burning gun-cotton to become ignited, except when the atmosphere in which the change takes place is so highly rarefied that the heat is immediately dissipated, and the gases evolved become highly attenuated, as already described.

It will be readily conceived that the mechanical state of the gun-cotton (*i. e.*, the particular form in which it is employed,) like other variable conditions which have been alluded to, will greatly influence the nature of phenomena observed when this substance is ignited in air, or in various gases, either at ordinary or diminished pressures. This may be exemplified by the following experimental illustrations. It has been stated that, when a tuft of carded gun-cotton is ignited in carbonic acid, carbonic oxide, nitrogen, coal gas, hydrogen, and other gases, it burns only with a pale yellow flame; this flame, when furnished by equal quantities of gun-cotton, is much smaller in an atmosphere of hydrogen than it is, for example, in carbonic acid; a fact which must be ascribed to the comparatively very rapid diffusion of the generated gases when hydrogen is used. In operating with pieces of gun-cotton yarn, instead of employing loose tufts, the material when ignited by a red-hot wire in atmospheres of carbonic acid, nitrogen in carbonic oxide, burns much more slowly than it does in air under the same conditions; and its combustion is accompanied only by a very small jet or pointed tongue of pale flame, which is thrown out in a line with the burning extremities of the piece of yarn. In the same way, if the yarn is enclosed in a tube or other vessel through which those gases are circulating, and from which one extremity of the gun-cotton protrudes, when the latter is lighted it will burn in the ordinary manner only until it reaches the opening of the tube, when the form of combustion will at once be changed to that just described. If, however, corresponding experiments are made in atmospheres of hydrogen or coal gas, the gun-cotton yarn will burn in the slow manner described, but only for a brief period—indeed, it ceases to burn at all almost instantaneously, just as it does when ignited in a very highly rarefied atmosphere. This result is not due to the high diffusive powers of the gas in which the gun-cotton is burned, as it may be obtained equally in open and in perfectly closed vessels; it can, therefore, only be ascribed to the high cooling powers, by convection, of the gases employed. Pure nitrogen, as stated just now, allows the gun-cotton yarn to burn in the slow manner, but if mixed with one-fourth its volume of hydrogen it arrests the combustion of the material, just like coal gas or pure hydrogen.

(To be continued.)

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, January 19*th*, 1864.

William Sellers, President, in the chair.

Washington Jones, Recording Secretary.

The minutes of the last meeting were read and approved.

The Board of Managers and Standing Committees reported their minutes.

The Board of Managers presented their annual report, which was read, accepted, and ordered to be printed with the minutes.

The Board reported donations to the Library from S. S. Halderman, Penna; Joel Giles, Esq., H. P. M. Berkinbine, Esq., J. J. Barclay, Esq., the Union League, and Prof. John F. Frazer, Philadelphia.

Frederick Arthur Paget, Esq., Civ. Eng. of London, England, was elected a corresponding member of the Institute.

The Special Committees on Weights, Measures, and Coinage of the United States, and on Expansion of Steam, reported progress.

The Report of the Special Committee on a Uniform System of Screw Threads, Bolt Heads and Nuts was considered, when,

On motion, it was ordered that printed copies of the Report be sent to persons and establishments interested in it, and that they be invited to communicate to the Institute their opinions on the subject.

On motion, a Special Committee was appointed to draft a memorial to the City Councils asking that action be taken, under the act passed by the State Legislature in April, 1864, for the appointment of an Inspector of Steam Boilers in the city of Philadelphia; and in making the necessary regulations for the government of the office; the Committee were instructed to report at the next meeting.

Committee Messrs. J. Vaughan Merrick, John H. Towne, John C. Cresson, Fairman Rogers, and Coleman Sellers.

The Tellers for the annual election for Officers, Managers and Auditors, for the ensuing year, reported the result as follows:—

President—William Sellers.

Vice-Presidents.

1. John H. Towne, 2. Fairman Rogers,
3. John F. Frazer.

Secretary—Henry Morton.
Treasurer—Frederick Fraley.

Managers.

B. Henry Bartol,
Pliny E. Chase,
Charles S. Close,
Charles H. Cramp,
James Dougherty,
Washington Jones,
J. Vaughan Merrick,
James S. Whitney,
Henry Cartright,
George Erety,
Frederick Graff,
Samuel Hart,
William J. Horstmann,
William A. Mitchell,
Bloomfield H. Moore,
Henry G. Morris,
George Harding,
W. Barnet LeVan,
Jacob Naylor,
Percival Roberts,
Samuel Sartain,
Coleman Sellers,
Samuel S. White,
O. Howard Wilson.

Auditors.

1. Samuel Mason,
2. James H. Cresson,
3. William Biddle.

Mr. Thomas Shaw exhibited his patent Lubricating Cup for steam engine cylinders, &c. This is so constructed that by a single revolution of a cock the oil will be transferred from the cup to the cylinder without the possibility of any escape of steam from the latter. Mr. S. also exhibited specimens of cylindrical glass tubing for steam gauges, made by Mr. Gillender. The opening in the tubing is broad in one direction and very narrow in the other, so that a small amount of Mercury shall present an extended surface. The specimen exhibited was remarkable for its uniformity in size.

Mr. Shaw also exhibited Mr. Blackwood's Hydraulic Jack, on the outside of the barrel of which is a chamber for the reception of a vertical plunger operated by a lever. This jack may be used either vertically or horizontally.

Mr. J. Field's improved Candle was exhibited. By means of an inverted cone at the lower end of this candle it will readily adapt itself to a candlestick having a socket of any of the usual sizes.

L. Saarboch's improved tobacco pipe was also exhibited.

Mr. J. H. Meissner exhibited his improved Bolt for securing armor plating to the side of vessels, &c. The ends of these bolts are similar to those of the bolt now in use, but a section near the centre of each bolt consists of plaited or twisted strands of wire which this section being welded or otherwise secured to the ends. The screwed point penetrates the wood at the back of the armor and retains the latter firmly in its place, while the elasticity of the wire section prevents the bolt from breaking when the plate is struck by a shot.

Prof. P. H. Vander Weyde submitted for the examination of the members a number of specimens of Photo-lithography.

Prof. Vander Weyde read a paper upon aerial navigation in which the history of the various flying machines was briefly given with some notice of the difficulties which are to be encountered and of the devices which have been suggested for overcoming them.

The Committee exhibited a patent Car or Carriage Spring, invented by Mr. U. B. Vidal.

By his arrangement of the spiral springs, a greater number of spirals can be introduced within a given area, than would otherwise be possible, while all the advantages of the pyromedal spring is secured, namely, greater extent of motion, because the folds of the spring fall within each other by pressure, instead of upon each other, as with the ordinary form of spiral spring, having thereby greater extent of motion.

By arranging the springs in screws one above the other with plates between each screw, will allow the use of short, stiff springs if desired, without loss of motion, as that may be obtained by additional tiers to make up the difference for the shortening the spring. His object in having slides on the side of the case or box, is to allow the ready examination, and if necessary, the removal of any of the springs, thereby saving time and trouble.

The Committee also exhibited a Gas Carburetter invented by Mr. U. B. Vidal.

Mr. V. proposed by the use of his apparatus to force the gas through coal oil, by which the illuminating power will be increased, the gas becoming saturated with the oil, which at the same time will act as a regulator to the flow of gas.

The case is supplied with oil to about one-third of its capacity, the gas is let on, the pressure of which raises the cup until the holes around its lower edge reaches near the surface of the oil, when the gas passes through the oil, into the outside case to the burner. As the gas is consumed, the cup rises and falls in regular motion, fast or slow, according to the pressure of the gas.

Annual Report of the Board of Managers, for the Year 1864.

In accordance with the By-Laws, the Board of Managers presents its Annual Report of the condition of the affairs of the Institute.

At its stated meeting in March last, upon the recommendation of the Board, the Institute caused an application to be made to the Legislature for such amendments to its Charter as would permit an extension of its scope and powers. This Charter was granted by the Legislature in April of last year, was approved and signed by the Governor on the 25th of the same month, and duly accepted by the Institute in the month following. The Charter thus granted permits the issue of Capital Stock and gives considerable latitude in the details of its organization, so that such alterations may be made from time to time as may appear to be expedient.

At the stated meeting held in June, the new Charter having been accepted, a set of By-Laws was adopted, which, among other changes provides for the transfer to the Board of Managers of the power hitherto exercised by the Institute in conducting its business affairs; the substitution of a resident Secretary, under compensation, to take charge of its library, scientific affairs, and correspondence, instead of the two Secretaries hitherto elected: and the election of all officers except the President, Secretary, and Treasurer, for three years, one-third being elected annually, thus giving a more permanent character to the policy of the Institute.

The present condition of the manufacturing interests of our City, which by their development have advanced her to the front rank of manufacturing localities in the country, renders the establishment of such an Institution as the Franklin Institute on a permanent basis an imperative necessity. To the well directed efforts of this Institute in past years much of this development is due, but the agencies by which it has worked hitherto, must, in some measure, be replaced by others more suited to the wants of the times, and in some respects, be made more practically useful.

Our library, already valuable in scientific works, and enriched by the collection of British Patents, requires enlargement and classification. More departments should be added to it, each of which, as well as each existing department should be increased by adding such works and periodicals as are required to keep its readers informed in the improvements and discoveries of the day. In this connexion it becomes a subject of interest to determine, whether great advantage might not be derived from such extension of its library as will include standard works not scientific in their character; by thus providing for the literary wants of members, a resort to other libraries would be unnecessary, and our own would become more attractive.

To our lectures on Mechanics and Chemistry, should be added others on subjects connected with their application to the arts.

The building now occupied has become inadequate to our purpose, and if longer used will require alterations so that its rooms may be more comfortable and attractive, as well as more suitable to the purposes for which they are used.

The stated meetings held monthly, might be made far more instructive by the presentation thereat of written papers on subjects connected with the practical arts, and discussions thereon. Steps have already been taken for this purpose; the meeting, being no longer in great measure devoted to the details of conducting the affairs of the Institute, more time is left for scientific discussion; and in December last the first of a series of papers was read on an important subject, that of Photo-lithography. It is believed that persons thus, familiar with the construction of great works in engineering or architecture, and with important processes of the arts, as well as those who may make discoveries in science, will find a suitable place and time for bringing them to public notice, and not only add to the general stock of knowledge, but by a comparison of views enlarge the minds of our members and lead to other discoveries and improvements. The additional interest thus created in the meetings, would render it desirable to hold them in the lecture room, thus avoiding any disturbance to those using the library.

The election of a suitable resident Secretary, whose presence at the Hall will render it always attractive to scientific or practical men, who will intelligently classify its library and see that it is supplied with the most valuable or recent works; who will select from domestic and foreign journals, each month, such valuable hints or descriptions as may be of general interest and who at the stated meeting will share this knowledge with the members, will, it is believed, modify the character of the Institute, making it more useful to its members in their business life, and more a place of resort to them, as the Exchange is to the merchant.

To carry out the improvements already indicated, as well as others which may suggest themselves, requires an expenditure far greater than the Institute, in its present condition, having upon its list many members who have ceased to contribute to its support, since it has ceased to hold exhibitions; and encumbered with a large debt and accumulated interest, the result of an unfortunate effort to advance its position many years ago, is able to carry out. Hence the necessity of enlarging its income, which we believe will be accomplished by the issue of the Stock.

This stock, to the amount of six thousand shares, of a par value of ten dollars each, represents the entire property of the Institute. Its security is good, because that property would bring in the market more than the entire amount of indebtedness. It is of two classes. The First Class, not registered for use, pays no annual fee and may be held to any amount by a single individual. It may, however, be converted into single shares of registered stock, (Second Class) when it becomes liable to an annual tax of three dollars per share. The annual fee for membership having been raised (from necessity) to five dollars, it is not only cheaper to hold a share, but the holder of the share has an ownership in the Institute while he enjoys every privilege of membership. The holder of ten shares not registered for use, enjoys the privileges of membership, and pays no annual fee. He is thus in all respects on a par with life members paying fifty dollars, with the additional advantage of bequeathing this privilege to his survivors or of assigning it to another.

It affords the Board much pleasure to state that by the efforts of individual members, nearly one-half of this stock has been subscribed in sums of 100 shares each by principal manufacturing houses and persons friendly to the arts, in this city; and they believe that a well directed effort on the part of their successors will result in the disposing of nearly all the balance of it in this way; so that a demand will immediately be created for the stock, by persons desirous of registering it for use.

The number of Life Members now on our list is 625, and of annual members in good standing 592, while about half as many more have their names still on the list but have not regularly paid their annual fees. During the past year 57 resignations have been accepted; 3 members have died; and 97 members have been elected; thus adding 37 to the membership. This result in the face of an increase of fees, is gratifying.

But it is hoped and believed that so soon as the efforts now making to re-organize the Institute shall have imparted to it increased vitality, and shall have shown the benefits it can confer, if conducted on an enlarged basis, our list of membership will be very greatly increased. Your Board believes that by its past history, and its past and present objects, the Franklin Institute has a just claim not only on Philadelphians, but on all who are benefited by the progress of the Mechanic Arts and especially on those who live by their exercise.

By the report of the Treasurer it will be seen that the receipts during the past year have been as follows:—

Balance in the Treasury, January 1st, 1864, .	$ 667·81
Receipts during the year, . .	9098·78
	$ 9766·59
And the expenditures have been, . .	9455·68
Leaving a balance in the Treasury of .	$ 310·91

And that the indebtedness of the Institute is as follows:—

	Principal.	Interest accumulated.
5 per cent. Loan,	13,650	4817·50
6 " "	4295	381·26
Mortgages,	7000	210·00
Temporary Loan,	500	110·50
	$ 25,445	$ 5519·26
	Total loan and Interest	$30,964·26

Annual interest payable on 5 per cent. Loan,	$ 682·50
" 6 " "	257·70
" Mortgages,	420·00
" Temporary Loan,	30·00
Total,	$ 1390·20

It is believed that an earnest effort to induce persons holding certificates of loan, to relinquish them in exchange for the stock of the Institute at par, would result in the sale of a considerable amount of stock and correspondingly reduce the liabilities of the Institute.

The Journal of the Institute, conducted since its foundation and now numbering 78 volumes, is still published monthly, and is a valuable record of the inventions and discoveries of the times. Its publication results in a small pecuniary loss to the Institute, but when its indirect value in the foreign and domestic exchanges is considered, this loss disappears.

During the past year the principal subjects of investigation have been, The adoption of a uniform standard of screw threads, bolt heads, and nuts for general use throughout the United States; and, A comparison of the results practically to be obtained by different measures of expansion of steam, to be determined by experiments now in progress in New York, under the auspices of the Navy Department, and conducted by a joint commission representing the Navy Department, the National Academy, and the Franklin Institute.

In conclusion, your Board would express the conviction that the changes now in progress, when fully consummated, will, with the hearty co-operation of the members of the Institute, be successful in enabling it to become a great instrument for good in the education of all classes in the mechanics and practical arts.

All of which is respectively submitted on behalf of the Board.

James Dougherty, *Chairman.*

A Comparison of some of the Meteorological Phenomena of JANUARY, 1865, *with those of* JANUARY, 1864, *and of the same month for* FOURTEEN *years, at Phila., Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	January, 1865.	January, 1864.	January, for 14 years.
Thermometer—Highest—degree, .	51·00°	65·00°	65·00°
“ “ date, .	10th.	29th.	29th, 1864.
“ Warmest day—Mean,	43·50	52·50	58·33
“ “ “ date,	10th.	28th.	15th, 1863.
“ Lowest—degree, .	6·00	7·00	—5·50
“ “ date, . .	28th.	2d.	23d, 1857.
“ Coldest day—Mean,	12·83	12·00	—1·00
“ “ “ date, .	27th.	2d.	9th, 1856.
“ Mean daily oscillation,	11·90	13·74	11·93
“ “ “ range, .	7·14	5·85	6·53
“ Means at 7 A. M., .	22·85	29·89	27·78
“ “ 2 P. M., .	29·90	37·48	35·27
“ “ 9 P. M., .	26·85	32·24	31·13
“ “ for the month,	26·53	33·20	31·39
Barometer—Highest—Inches, .	30·315 in.	30·271 in.	30·704 in.
“ “ date, . .	8th.	7th.	28th, 1853.
“ Greatest mean daily press.	30·303	30·207	30·609
“ “ date, . .	8th.	21st.	28th, 1853.
“ Lowest—Inches, . .	29·141	29·257	28·911
“ “ date, . .	7th.	19th.	23d, 1853.
“ Least mean daily press.,	29·402	29·347	29·086
“ “ date, . .	10th.	19th.	23d, 1853.
“ Mean daily range, .	0·234	0·206	0·218
“ Means at 7 A. M., .	29·843	29·886	29·956
“ “ 2 P. M., .	29·795	29·847	29·915
“ “ 9 P. M., .	29·828	29·913	29·945
“ “ for the month,	29·822	29·882	29·939
Force of Vapor—Greatest—Inches,	0·347 in.	0·396 in.	0·505 in.
“ “ “ date, .	10th.	1st.	11th, 1858.
“ “ Least—Inches, .	·051	·025	·023
“ “ “ date, .	28th.	2d.	22d, 1857.
“ “ Means at 7 A. M.,	·106	·133	·133
“ “ “ 2 P. M.,	·114	·137	·150
“ “ “ 9 P. M.,	·119	·140	·145
“ “ “ for the month,	·113	·137	·143
Relative Humidity—Greatest—per ct.,	96·0 per ct.	100·0 per ct.	100 per ct.
“ “ “ date,	6th.	18th.	often.
“ “ Least—per ct.,	40·0	34·0	24·0
“ “ “ date, .	14th.	26th & 28th.	25th, 1860.
“ “ Means at 7 A. M.,	81·1	73·1	79·8
“ “ “ 2 P. M.,	65·3	57·8	67·9
“ “ “ 9 P. M.,	75·6	69·5	76·3
“ “ for the month,	74·0	66·8	74·7
Clouds—Number of clear days,* .	9	13	8·9
“ “ cloudy days, .	22	18	22·1
“ Means of sky cov’d at 7 A. M.	50·0 per c.	60·0 per c.	62·3 per c.
“ “ “ “ 2 P. M.	65·8	52·9	63·0
“ “ “ “ 9 P. M.	45·8	41·6	48·4
“ “ “ for the month,	53·9	51·5	57·9
Rain and melted Snow—Amount,	3·598 in.	1·878	3·263 in.
No. of days on which Rain or Snow fell,	12·	10·	10·8
Prevailing Winds—Times in 1000,	N69°56′W·331	N78°41′W·319	N61°41′W·319

*Sky, one-third or less covered at the hours of observation

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

MARCH, 1865.

CIVIL ENGINEERING.

The Construction, Traction, Retardation, Safety, and Police of Railway Trains. By W. Bridges Adams.

From the Journ. Soc. of Arts, No. 629.

Wagons and carriages are kept short on railways in order that they may roll round curves. Viewing a train of wagons from a bridge, every wagon will be seen to oscillate from side to side on the rails, following the course of curves and irregularities. Every wagon is drawn by a loose coupling chain, some eighteen inches in length, and the oscillation is so violent that, though goods and coals suffer it, and suffer from it, it would be unendurable by passengers, so the carriages of passenger trains are close coupled together to keep them steady. But in this process the wheels, as constructed, are debarred from following their own courses and are compelled to slide. The result is a great wear of flanges and of axle-brasses, and a large consumption of coke. Were a train of goods wagons as close coupled as the passenger trains it would be simply impossible to move them. The first thing an engine-driver does, when about to start a goods train, is to back the whole of the wagons one on to another, and then start them one at a time in succession, by snatch after snatch at each chain, which is therefore required to be of enormous strength, in proportion to the resistance of the vehicle to traction by reason of bad structure.

The necessity for close coupling the passenger trains, arises solely from want of the efficient structure to induce free movement to make each carriage tractable instead of resisting—docile and not wilful. The first thing is to attain great length to prevent pitching movement, just as is the case with vessels on water. But with long vehicles, radial movement of the axles must be attained, as described in a former paper. Radial movement may be obtained by radial axle-boxes to the end wheels very effectually with one pair or two pairs of central wheels to serve as fulcra on the rails, or with frames of iron fixed to the axle-boxes and guided by the traction rod and buffer. The traction rod in such cases will serve in the same mode as a carriage pole on the highway. And swivelling buffer springs will, by coupling chains attached to the iron frames, keep the wheels in the right position while backing the train on curves. Or, if two pairs of wheels, coupled together at each end of the frame, be arranged with a quadrant or a pivot over one axle and a radial curved bar over the other axle of each pair, they will be self-guided on the rails, and a carriage thirty feet long may thus roll round a curve of fifty feet radius, and the steadier will it run, and the less will be the likelihood of getting off the rails, and moreover the less will be the proportionate dead weight of the vehicles to the available load it carries, if it be rightfully constructed. The Americans and other people use long carriages with swivelling trucks supported on a centre pin, which also have eight wheels, and thus radiate the axles imperfectly, though, if the trucks have not length enough, say two feet more than the width of the gauge between each pair of axles, they will not run steady, but will drag their wheels. If the radial system be applied, it would be quite possible to make carriages forty feet long with eight wheels to roll round a curve of 60 to 80 feet radius. A rough model of a vehicle of this description is on the table, and the guiding apparatus of the wheels is not intended for a bogy carrying the load, as in the American carriages, but simply a radial guide, the load of the upper frames being borne by the springs on the axle-boxes, with facility for elastic sliding, or swinging on long verticle shackles.

Some time back a series of medical papers appeared in the *Lancet*, on the subject of the injury experienced by a certain class of patients from railway traveling. The fact was strongly denied by railway authorities, and by many persons in good health who were not authorities. Not long back a railway engineer who had been very doubtful of the injury, informed the writer that he had changed his opinion, for, being out of health, and desiring to travel backwards and forwards to Brighton, he found he could not do it on account of the injury caused by the vibration.

It may be remembered, that when the Brighton line was first opened, numbers of City stock-brokers and merchants took houses at Brighton, and yearly tickets to travel up and down daily, in short, to live at Brighton, and transact their business daily in London. The writer has been informed that many ceased the daily practice at the end of the month, and at the end of six months it was found that hardly any could stand it and preserve their health.

Now, what is the reason of this? The carriages were as comforta ble and easy, and as well ventilated as an ordinary sitting room when not in motion, and the only difference therefore could be, that the sitting room is stationary, and the carriage moves. But what is the kind of movement? There must be something peculiar in it for physicians to order their nervous patients to travel by road and not by rail. There are two mechanical differences. The road carriage has wheels proper with independent movement and elastic wooden spokes, and elastic springs, and the wheels roll over a rough but not constantly hard surface. Riding in an omnibus along Cheapside, the rider finds the stone pavement hard and irregular, and the iron pavement much harder though regular, and the iron is the most unpleasant of the two.

The rail carriage has a kind of iron garden rollers for wheels, and they run on a small but hard iron surface. If the carriage be traveling at a mile an hour, as when starting from a station, the movement is scarcely perceptible, but when at thirty to forty miles an hour, the vibration becomes unpleasant to most, painful to many. In slow movement the wheels can adjust themselves to the rails, and roll or slide easily. In rapid movement they have no time to adjust themselves, but slide, as well as roll with incessant jerking. On very sharp curves the movement is sometimes all sliding.

It is this sliding which constitutes the difference. We may illustrate it as follows. Everybody knows that the sound of a violin is induced by rubbing the horse hair string of a bow over the strings of the violin, both being in tension. But the simple horse hair will not produce the effect. To produce sound the player applies powdered resin to the horse hair to induce friction, and it is the leaping of these particles over the strings that induces the vibration resulting in "sweet noise." Sometimes, those who love loud laughter better than sweet noise, will, as a practical joke, apply a tallow candle surreptitiously to the horse hair bow instead of resin, and then the vibration causing the "sweet noise" is stilled. Now the wheels on a rail are a contact of practically rough surface, which vibrate and induce torsion of the axle, and thus vibrate and jump, and the result is, not "sweet noise," but very unpleasant noise and jarring, which, if long enough continued, makes a nervous passenger ill, and tends more or less to counteract the peristaltic motion of the intestinal canal. If the rails and tires were rubbed with the tallow candle before alluded to, the vibration would cease, at least till sand enough had accumulated to counteract the effect of the tallow. But the engine-driver would not approve of this plan, as it would lessen the power of haulage.

How, then, is this vibration to be lessened? First, by lessening the hardness of the rail, and rendering it elastic. Secondly, by rendering the wheels elastic. Thirdly, by permitting wheels, or tires, or both, to revolve independently of each other. Fourthly, by radiating the axles so that neither on curves nor straight lines will the wheel flanges be ground against the rails. Fifthly, by efficiently springing the carriages, using a double series of springs, as well known in private carriages. Sixthly, interposing a non-vibrating material, such as india-rubber, between the carriage body and frame. Seventhly, by so constructing the bodies that passengers may stand or sit at pleasure. The blood cannot circulate freely when in a constant sitting position. Sedentary employment is a common source of paralysis.

The next question is that of brakes in absorbing momentum by friction. When a large mass of material is put in motion it requires at first a much greater amount of power to start it into motion than it does to keep up that motion when speed is attained. The power required to get up the speed is called momentum, and if it be required to stop the momentum it must be absorbed by friction or gravity. If the stopping places of railways were always on ascents there would be no need for brakes; gravity would supply the place of friction. And if the starting places were always on descents, little surplus power would be needed to produce momentum, as gravitation would furnish it. But momentum has to be absorbed under many varying circumstances,—sudden obstacles to be averted or stopped short of,—stoppage at stations,—and the descent of long inclines; also the ascent of long inclines, in case of couplings breaking or wheels slipping.

In the early times of tramways the Convoy (*convoi*) or brake carriage was used with the train. In the early times of railways brakes were applied to first-class carriages, each worked by a guard, because the first-class were the heaviest. But people who paid first-class fares demurred to this, and sliding brakes were adopted, working on the wheels and axles without attachment to the body, and thus jar was lessened but noise was increased, and so the brakes were transferred to the second class, and then the old Convoy—the brake van—was revived, one at the head of the train next the tender, and the other at the tail, and when the train was heavy, one in the middle. But it was to a very small portion of the total weight of the train that the break power was applied, and the guards screwed down the blocks tight, and so skidded the wheels and ground flat places on the tires; and to apply brakes rightly every wheel in the train should have a brake block applied lightly to it, from the engine to the last carriage. The engine should have brakes pressing on both rails and wheels, applied by the driver, through the agency of steam friction, by simply turning a steam cock, the pressure being divided between the rails and wheels in any convenient proportion. Brakes on every vehicle in the train and on all the wheels would reduce the pressure required on each to a minimum. The system of "continuous brakes," as they are called, is applied to as many vehicles as the power used can reach. But the power used is commonly hand-power, and that is limited.

A new mode has lately been adopted on the North London line of making the momentum destroy itself. On this line of short mileage and many stations, with frequent trains, it would not be possible to work the traffic without the means of rapid stoppage, *i. e.*, the utmost rapidity short of concussion. For this purpose a chain of sufficient strength to draw the whole train is extended beneath and throughout the train. When this chain is drawn straight, the blocks are all on to every wheel, and when the chain sinks into a succession of curves, or bights, by a weight beneath each carriage, the brakes are all off.

To draw the chain straight, a pair of heavy cast iron disk wheels, with a barrel or drum on their axle, are then suspended in slings below the last carriage. The guard, by means of a screw, brings these suspended wheels into close contact with the running wheels of the carriage, and the friction causes the disk wheels to revolve by the momentum and to wind up the continuous chain on the barrel till it is drawn straight, and the brakes are all on, when the disk wheels begin to slip, and the momentum of the train is absorbed by the brakes. In this mode a train of fifty vehicles may be stopped in as short a space as a single vehicle, the right amount of friction being applied to each. This arrangement, however, requires either that the chain be carried through the whole train, and accurately connected with the proper lengths of chain to each carriage, the whole train being pulled close together, or that the break-van at one end and the engine at the other, serve as fixed points to lift the counterbalance weights and draw the chain to a straight line. There is no doubt of this acting well on trains fitted for the purpose, but the writer has not yet seen it applied to mixed and irregularly made up trains.

With regard to the application of brake blocks, there is an advantageous and a disadvantageous method. If applied to the fronts of the wheels, that is in the direction of the pulling engine, they do not chatter on the wheels, whether fast, or loosely applied, but when brought into contact with the backs of the wheels they do chatter, till the pressure becomes very strong, so strong indeed as to skid the wheel. The longer the block, *i. e.*, the longer the surface of tire it embraces, the less is the chatter. But it would be far better to arrange the blocks between adjoining wheels, so as to press both rail and wheels, and in this mode there would be no chatter.

But though the continuous brakes before described act so well on continuous trains of vehicles, the action depends wholly on the continuity of the chain, as well as quick movement to apply them. If the chain separates, the brake action ceases at once, and this on a steep gradient might be disadvantageous. It is, therefore, desirable to have the brakes self-acting, if possible, without depending on the human hand, and operating on every vehicle independently of the others—operating also instantaneously when required. The writer was led to study this question, owing to the necessity of enabling the brakes to follow the wheels of radial carriages on curved courses.

To put this in practice brake blocks are suspended from cross shafts attached to frames resting on the axle-boxes of the wheels. To these blocks long weighted levers are fixed, which cause the blocks to press against the wheels with either a steelyard action or, what is called, an elbow joint, four blocks being used, one to each wheel, with two levers or rods to cross bars. Thus the normal condition of the blocks is, to be pressing on the wheels with a power sufficient for the purpose. The lever ends are attached to the brakes rod by a chain passing between two pulleys on the carriage frame, and as in the process of traction the rod moves lengthlong in the carriage to either end, the chain lifts the levers vertically, the traction force of each vehicle being sufficient for this purpose, and this process operates on every vehicle so fitted, even though ordinary vehicles be interspersed in the train; and in ascending an incline, if a traction coupling parts or breaks, these self-acting brakes will instantly press on the wheels before back movement of the wheels can commence; and in going down hill the brakes will be lifted while the engine is pulling, but will be in action directly the engine is slowed, and they may thus go on pressing and lifting, and so moderating the speed down an incline. It may be objected that the power of the brakes might thus be in excess, and so be a disadvantage, but to equalize this, every vehicle is to be provided with a hand lever, which will enable the driver to put temporarily out of action as many brakes as he may choose, leaving in action the number required for his purpose. The model of the carriage on the table is on a length of rail which may be placed on the level, or at angles of one in 1, in 20, 60, 50, 40, 30, 20, and 10. It will be found that brakes so applied, will retain the vehicle on an incline of one in fifteen, and by snatching the brakes rapidly off and on, starting and stopping may be rapidly performed. In practice the ends of the levers may have sliding balance weights applied, so as to increase or diminish the pressure by the length of the leverage. It must be borne in mind, that the tractive force required to draw the wagon while running, must govern the weight required to be lifted at the brake levers, and in cases where much weight is needed, the mechanism for lifting must be arranged accordingly. When the whole of the wheels are provided with brake-blocks, a comparatively slight pressure on each tire will suffice.

The longer the vehicle the longer may the brake lever be, and the more effective will the vehicles be both for goods and passengers. Coal wagons are made short, for the convenience of getting close to the pit's mouth, but the model on the table, representing a wagon 30 feet in length, will roll round curves of 50 feet radius, and by its great steadiness will carry the coal—a very friable substance, with far less breakage. And a long wagon may be made considerably lighter in proportionate dead weight than two short ones, thus adding to the available load. In these days of competition in coal transit, this is a very important consideration. The self-adjusting brakes described will work equally well, whether the engines be on straight lines or sharp curves as the levers are arranged to act equally well in either case. And as it is needful occasionally to back the train, for which purpose the brakes must be out of action, this may be accomplished by connecting the traction rod to the buffer rods or buffers by spring agency, so that the thrust of the engine may lift the chains and brake levers in succession, and put the whole out of action, or they may be lifted by hand levers as at present practised. This class of brakes is especially adapted to steep gradients. There is nothing new in the principle now proposed. It is the safety principle in the cages of mining shafts and on some railways with rope traction.

The last question we have to deal with is what we may call the police of railway trains. This is a question of structure. Trains are subject to catch fire on the roof; passengers may be taken suddenly ill; murders may be taking place, or other violence, but the sound of the train deadens all other sounds, and neither driver nor guard knows of it. And so there is an outcry for communication between passenger and guard, and guard and driver. And there are propositions for galleries outside the carriages for guards to walk along and catch murderers in the act. It seems to be forgotten that this facility for the guard would also be a facility for the thief or murderer. The practicability of these things is not considered. It is common to talk of the "six-foot" between the two lines of rails, as giving ample space for the guard's gymnastics, forgetting that the "six-foot" is reduced to two feet by the overhanging carriages, and that two guards on opposite lines would thus come into collision, and, in American phrase, be "rubbed out."

If the guard is to patrol the train, there is but one way of doing it —through the inside—a passage-way through the whole length of the train. Third class would probably not object to this, as they are disposed to be gregarious, and would not object to a guard or policeman additional, but second class might object, and first class assuredly would, on the score that they had paid their money for space and privacy. If it were put to the vote there is little doubt that the vote would be for privacy and a certain amount of risk, rather than gregariousness without risk. It must have been a matter of observation to those witnessing the starting of trains, how first class passengers walk along till they find an empty compartment, and, failing in this, make for one with the fewest occupants. And second class will do the same.

Were the lines single there would be no difficulty, as the carriages might be widened at least to the full extent of the tunnels, but with double lines the "six-foot" is the limit, and sometimes the "six-foot" is only five feet, and even less. With the six feet it would be practicable to have carriages two feet wider, provided only that the passengers would consent to have a wire guard to the windows limiting the protrusion of their hands, like the grating to the windows of a Spanish house. With a carriage ten feet wide, it would be quite practicable to have a closed passage in the centre, two feet wide, and compartments for four persons each, thus getting rid of the objectionable centre seats. The external doors would be retained, there would be sliding doors inside opening into the central passage, communicating with end platforms. The second class and third would dispense with the closed passage. Sliding doors, glazed, would prevent the entrance of wind or rain through the central avenues. In this mode it would not be merely on the guard that the passengers would rely on for protection, but also on the intercommunication with each other in case of necessity. But if the brakers were all left to the driver, as they should be, the guard would have ample leisure to attend to the police of his train, instead of having his time taken up with the mechanism. Great Western carriages in the first class are divided lengthlong by a partition with the disadvantage that the compartment next the platform on the near side has to serve as an ante-room to the other. If the carriages were two feet wider this difficulty might be avoided by a central passage. No doubt this might be all very much simplified by making the whole train a series of open saloons, as in America, but public taste must decide this; and even in America they are now beginning the system of private compartments. With the exception of occasional alterations at platforms, it would be quite a practicable thing to widen the whole of the existing carriage bodies, by dividing them in the centre longitudinally and inserting the extra width as ships are occasionally dealt with to lengthen them. And there would be one considerable advantage, that by widening the train the length might be shortened, or a larger number might be carried. It may be objected that a small number—four persons—in one compartment might involve a risk in plotted crime; but it would be quite practicable to make one side of the vehicle closed and the other open compartments.

As a matter of safety in collision, the larger carriages are preferable, as they do not mount on each other's backs. As regards the expenditure of momentum by sudden stoppage, which throws passengers violently in each other's faces, the safe remedy would be setting sideways instead of fore and aft; they would be shoulder to shoulder, and in the safest position; but even in this case it is possible that they would prefer the ordinary position with risk, to side-sitting without risk, at least till they had a practical verification by frontal damage to their persons. The subject is so large that the writer has only dealt with it summarily, but a useful purpose will have been answered should the paper have given new materials for thinking.

In conclusion it will be well to help the memory of the reader by a summary of the various proposition contained in the two papers having reference to the amendment of corresponding defects:—

1. Spring tiers for the purpose of preventing blows and friction and lessening the chances of the wheels escaping from the rails, a system thoroughly verified in practice, as quadrupling the durability.

2. Systems of an elastic permanent railway, supporting the rails by continuous elastic bearing, preventing disintegration of the rails as verified in practice.

3. Improved system of fish-joints, duplicating the strength, with elastic fit of ribs and bolts.

4. Radial axle boxes, to enable locomotives of great length to pass round any sharp curve without friction on their flanges.

5. Eight-wheel tank engines for sharp curves of 99 feet radius, long verified in practice.

6. Eight-wheel tank engines, for curves of 99 feet radius, all eight wheels drivers, both on straight lines and curves, by means of superimproved friction-wheels, all capable of retardation by steam brakes, making the whole weight of the engine available for traction or retardation.

7. System of V flanges to spring wires working into V grooves of rails, to obtain increased bite for ascending steep inclines, or when starting with heavy trains.

8. System of long wagons and carriages on eight wheels, radial axles, and guided by quadrants, with sliding springs, or long swinging shackles, to roll truly round curves of from forty to eighty feet radius, and provided with self-acting brakes, to prevent accidents on steep inclines—economically and easily carrying large loads.

9. Mode of constructing passenger carriages to give free internal circulation to guard, engine-driver, and passengers without interfering with the privacy of first class passengers.

These principals and plans are applicable to all gauges, from 7 ft. to 3 ft. 6 inches light lines.

(To be Continued.)

On the Mechanical conditions of Railway working to prevent Destructive Wear and Risk. By W. Bridges Adams.

From the Journal of the Society of Arts, No. 628.

This is a subject not of mere local or of class interest. In days gone by, when a man was by the mass of Cockneys esteemed a traveler if he had been to Gravesend and back, it would have interested but a very few to discourse on the means of transit, but in the present day, all men, women, and children have become locomotists, getting back to a state of nature, like the birds and wild animals, and no longer confined to the spot on which they are born and bred. And a very good thing it is for themselves and general humanity, for they thereby become educated, not in the sense of book learning, but in the sense of knowledge of men and things, expanding their thinking faculties with the more healthy growth of their bodies. We increase thereby the number of men and women, instead of mere human animals, and we increase also national power, which is not to be measured by animal units, but by the mass of intelligence, health, and physical strength—in short vitality. It is better to soar like birds than to burrow like rats; and though we cannot soar above the earth, with guiding power like birds, we contrive to skim along the surface though not quite so fast, and do not yet see our ultimate limit to speed accompanied by safety. We are fast becoming a nation of mechanicians, and each man's strength is as the strength of ten, as fast as he acquires a sound body for a sound mind to dwell in. The subject is possibly a dry one in its details, but out of these dry facts must come the growth of progress, and this must be the writer's apology for dwelling on them, though in as succinct a mode as language will permit. In criticising any subject it is but natural that the critic should devise plans for amending that which he deems wrong, and in so-doing the writer would deprecate any appearance of egotism in dealing with his own plans.

In vehicular transport the contact between the vehicle and the road it moves on may be of three kinds, sliding, sledging, or rolling. The sliding movement may be converted into rolling by the application of water, oil, or unguents, the particles of which form rolling bodies between the vehicle and the road, as with the ship on water, or with the wine sledges used in Madeira, where the driver sluices the road beneath the sledge runners, or with the winter sledges of cold climates, where frozen surfaces supply rolling particles. If actual contact between the moving vehicle and the road take place without the intervention of rollers or lubricants, destruction must ensue by abrasion.

Where no means exist of supplying lubricants to the road surface, the next process to ease the sledge is to place rollers under it. If the rollers be true cylinders, and are not fixed to the sledge, and the movement be in a straight line, there will be absolute movement without friction. If the rollers be fixed to the sledge, by axles passing through them and bearing the load, the friction will be transferred to the surface of the axle from the surface of the road, and will be greatly reduced if the oil or unguent forms an efficient lubricant. If the roller bears on the road through its length, and be a true cylinder, it will move forward in a straight line. If it be of a conical form it will move in a curved line corresponding to a cone. But if two coned rollers be fixed to the sledge with their axles parallel, the movement will be partly sliding and partly rolling, with great friction in a straight line. If the two coned rollers be not parallel, but are arranged with their axles in converging lines corresponding to the cones, the machine will move in a circle, the centre of which will be the point where the converging lines intersect each other.

The ancient Greek and Roman cars were mounted on rollers, *i. e.*, a pair of wheels connected by a fixed axle running between thole-pins, such as up to the present day we see in the wine-cart of Portugal and parts of Spain, which are unfitted to turn corners, and make so fearful a squeaking when running out of a straight line as to give rise to the jest that they are so ordered to give warning to the custom-house officer in case of smuggling. Double-roller cars also existed, with fixed parallel axles, and this faulty mechanism was probably one cause why the old Roman roads were made in straight lines, as it was easier for such cars to run up hill than to follow curves. Even supposing the case of four-wheeled cars with two wheels running independently on their axles, these cars could still only run in straight lines as long as their axles were rigidly parallel; and in England it was only during the reign of Queen Elizabeth that what were called "turning carriages" first existed, *i. e.*, with a mechanism that permitted the axles to depart from their fixed parallelism to pass round curves.

When railways, as distinguished from tramways, were first commenced, the faulty mechanism of the early classic cars was resorted to as a cheap structure—cheap in first cost. Wheels proper were ignored—*i. e.*, wheels running independently on their axles—and rollers *i. e.*, two wheels fixed to a shaft or axle which revolved with them in thole-pins, or what are now called horn-plates. And, whether two axles or three or more were used, they were always rigidly parallel. And this is the common practice in England to this day.

What are called tramways are formed of flat plates of iron, with rising edges to keep the wheels in track. Ordinary wheels, revolving independently on their axles, were used on them. Their mechanical disadvantage was that dust and dirt accumulated on the horizontal plates, and the wheels rubbed hard against the rising edges as against kerbstone, and caused much friction. Opinions are divided as to the origin of the term tramway, whether derived from an originator named Outram, or from the word "trammel," to curb or guide. The term "platelayer," on railways, is evidently derived from the original tramplates. On railways proper, what is called the edge rail is used, in which the increased depth gives greatly increased strength to support the load, and at the same time, dust and dirt have but little chance of remaining on the rails. But to keep the wheels on, the rising ridge or kerb of the tramway is transferred to the wheel, in the form of a flange. It is clear that vehicles with fixed wheels and parallel axles are only adapted to move in straight lines. If the axles were converging, the vehicles would only move in curved lines. But there is another common condition, a result of faulty workmanship—parallel axles not at right angles to the line of traction; in this case the machine becomes a sledge under all conditions, with the wheel flanges constantly grinding against the rails.

With a view to compensate, on curved lines of rails, for the different lengths of pathway on the two rails, it has been a practice to make the wheel peripheries conical instead of cylindrical; *i. e.*, each pair of wheels fixed on the axle being practically a garden roller, with the central portion removed, are made at each end a frustrum of a cone, with the smallest diameters outside. Were the roller solid, *i. e.*, were the coned lines prolonged till they met in the centre, the roller, if balanced, might run in a straight line, or it might run in a curved line, to right or left, if bearing on either cone, the curve being regulated by the angle of the cone. This would be the case with a single roller. But it is a fallacy to suppose that two or more rollers fixed in a frame with their axles permanently parallel, would follow the same conditions, even though sufficient end-play were allowed between the flanges and the rails to make the differing diameters across the breadth of the tires available to compensate for the differing lengths of the rails. The movement in a straight line might be free rolling at low speed, provided the cones had sufficient lateral movement or end-play, but on curves it would only be sliding or sledging. But if the frames were so arranged that the axles were permanently out of parallel by reason of careless workmanship, the machine would be a constant sledge both on straight and curved lines. So also if the axles were perfectly parallel, with the wheels in the same plane, but were not placed at a right angle with the line of traction, the result would be constant sliding friction.

In any of these four conditions—whether a truly constructed frame, with parallel axles, or badly constructed with axles out of parallel, or badly constructed with parallel axles and wheels out of plane, or not at a right angle with the traction rod, though the first may roll at intervals under a favorable condition, the three latter must always slide, and the resistance to traction will be in proportion to the roughness of the rails and the load on them. With a light vehicle, little loaded, smooth wheels and polished tires and rails, and especially if they were lubricated on the surface, the resistance might be very small. Nay, a sledge might even be better than a wheeled vehicle, if only the condition of a lubricant could be retained. But a lubricant on the rail is inadmissible, first, because it would cause dirt to adhere to the rail, and secondly, it would defeat the condition of adhesion essential to the traction by the locomotive engine. The engine needs the greatest possible amount of adhesion, corresponding to the steam power. The vehicles should be so constructed as to minimize the amount of resistance. But as at present constructed, the vehicles on a railway are in principle a reproduction of the old Roman cars on two rollers, with such variation as a better or worse condition of workmanship or lubricant may induce, and the change from a common road to a railroad.

Axle friction, under the best condition, is commonly estimated at about four pounds per ton of load, but this is usually doubled by a condition, that under the best treatment ought scarcely to exist, viz: "rolling friction" *i. e.*, the friction of the tires on the rail, and thus at a moderate speed on the level, eight pounds per ton is estimated as train resistance. But this, it is well known, is very far short of the real resistance in practice, which by quick curves and bad structure may be quadrupled and quintupled, varying with the speed of movement.

A river running with a slow movement may pass along a winding channel without disturbing its banks; but the same river, with its speed increased by a sudden influx of water, seeks to make a straight course and cuts away its banks, or *rives* them, in a mode corresponding to its etymology. Even so, a railway train at high speed becomes a *river* of the rails, at an increased cost of coke converted into steam; and, like the river water, it produces debris, not in the form of gravel, but of black iron powder, as any one may verify by rubbing his finger along the rails after the passage of a train. This is frictional destruction, increased or diminished, in proportion to the load on each wheel.

But there is yet another element of destruction—percussion or blows which take place between wheel and rail, friction or percussion being the only sources of mechanical destruction on railways—the others being chemical. It is quite clear that were a train to stand still on a railway, and never move, it might rust and rot, but it would not wear out, and though the proverb is a sound one "better rub than rust," it is still better to do neither. The movement of the train begins the great destruction, and it is want of compensation for irregularities—a condition never disregarded by nature—that causes the destruction. The wheels, when running on unequal paths, induce great torsion of the axles by friction on the rails. At bad joints or uneven surfaces the wheels jump from the rails, and they then recover their normal position, by the axle as it were unwinding itself like a discharged spring, and striking a violent blow on the rail. Sometimes the wheels, with the axles in a state of torsion, drag along for a considerable distance, heavily loaded, and this is a fruitful source of axle breakage as well as of rail destruction. Again the flanges strike against the rails from side to side, and a constant succession of blows and vibrations is induced throughout the whole of the train. And with long vehicles, on sharp curves, there is a constant tendency to grind the flanges and burst out the rails. The rapid wear of wheel tires and rails yields ample evidence of this, and the probability is that at high speed the movement is as much sliding as rolling—side as well as forward sliding. But for the partially polished surfaces of both wheels and tires facilitating slip, at the loss of adhesion on the driving wheels, it is probable that the destruction would be much more rapid.

Are there proofs needed of all this? Time was that rails of 60 lbs per yard, and Staffordshire tires too tough in texture to break, were capable of considerable duration. They have gone by, and rails, after various experiments in making them harder in iron, have grown to 84 and 90 lbs per yard, and now with Bessemer steel for metal; and tires, after running through the phases of Park-gate, Low Moor, and Leeds, and various plans for steeling their surfaces, have now culminated in Krupp's solid steel.

It is many years since the writer became aware of the importance of elastic action, even on wood wheels used on highways and paved streets, to induce durability, and facilitate traction, when high speeds were needed. In the structure of the ordinary wood wheel the strength resides in the tyre, which keeps the weak frame together. Originally, wheels were made vertical, *i. e.*, with the spokes all in a plane, and the width of base was determined by the ruts or hollows which pervaded all roads, giving a kind of fixed gauge, much as rails do now. The bodies were placed between the upper part of the wheels; and when it was needed to widen the bodies, the wheels were made in the form of a cone, or what is called "dished," the axle-arms being pitched downwards to keep the lower spokes vertical, with an idea of strength, while the upper spokes inclined outwards with a considerable angle. The fellies and tire were made conical, to preserve a flat tread on the ground. It is evident that as these wheels revolved, they were constantly grinding the road, the outer side of broad wheels being considerably less in diameter than the inner, while the vertical spokes were continually driving into the nave and loosening the framing.

After trying some experiments with wheels in which hoops of elastic steel were used to connect the periphery with the nave, instead of spokes, the writer had some made with the section of the wood spokes reversed. The ordinary mode is to make the spokes deepest from back to front, but in the improved samples were made broad in the plane of the wheel, and thin from front to back. As this was a bad form to fasten in the ordinary nave, it was dispensed with, and a pair of disk wheels were substituted, between which the spokes were mitred together and bolted. One felly was used to each spoke, instead of the ordinary practice of one felly to two spokes, and when cylindrical tires —not conical—were shrunk on, the spokes curved from back to front, and the wheel, instead of being a rigid cone, or dish, became an elastic dome each pair of opposite spokes radiating from the centre, representing the form of an archer's bow. The fastening of the tires was through the joints of the fellies. When applied to a straight axle, with the arms not pitched downwards, the load was carried, not on a rigid vertical, but on a bent inclined spoke, and the result was that the load was not only carried more easily, but the wheels were, for their scantling, the most durable ever constructed.

In the early railway wheels the principle obtained of neglecting the structure of the frame, and making it depend for strength on the shrinking of the tire, just as wood wheels were made. One result of this was the flattening of the tire between the spokes, and a tire of unequal thickness, when turned in the lathe to make the external periphery a true circle, and a consequent rapid destruction in wear. This applied to the wheels with the wrought iron spokes. The truest formed wheels were those of cast iron with a wrought tire. They might break if of careless moulding, but they would not otherwise alter their form, and the tires could be all of equal thickness. But upon rigid cast iron wheels the tires became exposed to very rapid destruction as the loads increased.

The writer had early turned his attention to the importance of wood wheels for railways, and as far back as the year 1838 caused some to be constructed with two rows of fellies, break-joint between the tire, and a cast centre. They worked well, and the writer has been informed that they still exist. The difference between these wheels and the modern wood wheels is that they had the elastic side grain on the tread, whereas the modern wheels have end grain. The reason for substituting the latter less perfect method probably was the difficulty of ensuring dry timber on a large scale, and wood shrinks scarcely at all endwise, so that the shrinkage involves less evil.

Wood wheels on railways are, as now made, solid disks, and therefore the frame preserves its circular form without being excessively rigid. Iron wheels have also been made in the disk form, both in cast and wrought iron; but, then extreme rigidity rendered the destruction of the tires a very rapid process;—the tire was between two anvils—the frame of the wheel, and the rail supported on chairs of cast iron.

To prevent this destruction the writer early devised a wheel in which the spokes were all springs, but that did not answer, because the bending of the spokes prevented the wheel from running true. The next plan was to apply a hoop of elastic steel between the tire and the periphery of the wheel, with a hollow below the steel. The wheel was retained in the tire by a rising rib in front, solid with the tire, and by a lower rib behind, sprung into a groove of the tire. Models are on the table and a section on the wall.

The plan was satisfactory in theory, but how to put it in practice was another matter. A railway was needed, and railways are not to be found in a private field or park; they are the highroads of the public, and in charge of officers whose first care is to take no risk by an unknown plan; for if an accident happens through a known plan in common use, however faulty in its mechanical philosophy, a jury will acquit the manager of all blame. But if the accident happens with a novel plan, however theoretically right it may be, the jury will probably condemn it as new-fangled, and saddle the manager or engineer with the blame; and thus there is a natural indisposition in engineers to step beyond their tether into the unknown, and they can hardly be blamed for their caution.

So the writer went forth on his propaganda to expound an unknown quantity, but few would even listen to him, and none would believe; but strong in faith he persevered, and at length found an engineer with a logical mind, in the locomotive superintendent of the North London Railway, Mr. William Adams. The writer demonstrated his principle, and Mr. Adams was unable to disprove it logically whereon the writer remarked; "If you cannot demonstrate it to be wrong, and I demonstrate it to be right, and that the result if successful must be very advantageous, you are bound to try it." He agreed to this, and said "I will try it, though doubting greatly. What wheels will you apply to it?" "Those most destructive to tires."

So a set of wrought iron disk wheels were selected, and Staffordshire tires were applied to them on hoop springs, and they were placed under a heavy carriage. At the same time a set of ordinary spoke wheels, with a set of Low Moor tires fixed in the rigid mode, were applied to a similar carriage. The Low Moor tires required turning up to restore their surface after running less than 50,000 miles. The Staffordshire tires on springs ran 106,000 miles without turning up, and with no alteration of form, and were then taken off to exhibit, and may still be seen in the same condition.

There is no mystery in this. The Low Moor tires were exposed to severe wear. First, because on curved lines they were necessarily forced to slide on the rails, both forward and laterally. Secondly, because they were rigidly fixed, and possessed no elastic yielding to elude blows. Thirdly, because on curved lines there was a constant torsion of the axles causing incessant jumping. Fourthly, because the tires had no power of lateral movement to suit the varying inequalities of the rails. In short there was no compensation for irregular movement, and the result was a constant grinding of the flanges and treads.

With the spring tires, on the contrary, there is universal compensation. First, there is no tendency to blows, because the elastic cushion preserves constant contact between tire and rail. Secondly, there is no torsion of the axle or slipping of the tires on the rail because the wheel can, on curved lines, slip in the tire on the smooth surface of the spring without damage, thus equalizing the pathway. Thirdly, the tire can rock laterally on the wheel to adjust itself to the bearing on the rail surface, which any one may observe to be constantly varying, sometimes the middle of the rail being most prominent, sometimes the inside edge, and sometimes the outside. No other class of wheel can supply these various compensations.

Important as these wheels are for vehicles which are simply drawn, in order to remove resistance, they are still more important for engines with the load greatly increased, and especially for driving wheels—more especially for engines with four coupled drivers. It is obvious that if two wheels of equal diameters be fixed on the same crank shaft they must grind and drag on curved lines, and the torsion thence ensuing is the main cause of the breakage of crank axles, which it is difficult to make strong enough for their work, the axle being in reality a very long axle, as would be readily apparent were it stretched to a straight line—between eight and nine feet long on the narrow gauge. When four wheels are coupled, the diameters very rapidly alter by irregular movement, and the adhesion may actually become disadvantageous, retarding the engine by friction, like a brake. It is clear therefore that the power of slipping the wheel within the tire to compensate for curves and irregularities becomes a question of the greatest importance, both as to facilitating haulage and preventing the wear of tires.

It has been at times assumed that the slip of the tire on a wheel must defeat the purpose of haulage. But when it is remembered that the bearing of the wheel is over half the diameter by downward pressure, and that with a heavily-loaded wheel a slight flattening of the tire takes place, it is obvious enough that slip will only take place by excessive friction on the rail; this is the true theory, but, for the satisfaction of those who only believe in practical results, it may be stated that the experiment has been tried repeatedly, and it has been found that when the tires were so loose on the springs as to be turned round by hand with the wheel lifted, the haulage was in no way affected. On a London line, of sharp curves, where the leading tires of ordinary engines with parallel axles had their flanges constantly ground off in two months wear, a bogy-engine was set to work with a turning centre to radiate the leading axle to the curves. At the same time a similar sized engine, but with parallel axles, was applied with spring tires to the leading wheels. The result was that in both cases the leading flanges were saved from damage, and ran three times the ordinary distance. The yield of the springs had an effect similar to that of the play of the axle to right and left in the bogy, when truly centred, for if not truly centred the flanges wore unequally.

These spring tires were adopted on the engines of the St. Helen's line, by Mr. James Cross, the engineer. That line is an incessant continuation of sharp curves and gradients, some of the latter 1 in 35, and some of the former two chains radius. The spring tires were first applied to a six-wheeled engine, all coupled drivers of 4 ft. diameter. They were all of Staffordshire iron. At the same time another engine of less weight, also on six wheels but of 4 ft. 6 ins. in diameter, and only four coupled, was fitted with tires of Krupp's steel. After running 41,000 miles, Krupp's tires was so deeply worn as to need turning up, while the Staffordshire iron tires ran 65,000 miles, and then only required the flanges to be reduced which had been deeper at the outset, the tread of the tire remaining in good shape. Taking into consideration the difference of diameter, the distance run by the Staffordshire iron was as 72,000 against Krupp's steel 41,000. In practice, Krupp's tires was found to slip on the rails even in dry weather, but the Staffordshire iron was scarcely ever known to slip, though working steeper gradients and sharper curves.

Another set of experiments was tried with two fellow engines, one of them fitted with spring tires, the other with rigid tires, up a gradient of 1 in 80, during a whole day, by the same driver. The result was, that the rigid tires constantly drew up 13 loaded coal wagons, and the spring tires fifteen.

The result of this elastic principle having been so unmistakably advantageous in wheels, the writer began to consider whether the same principle might not be practically applicable to rails also. It is clear that the destruction of rails arises from blows between the wheel tires and the rails, increased in destructive effect in proportion to the load, and therefore it is, that it is now proposed by some railway companies to substitute steel for iron in rails as well as tires.

On the North London Railway, the rails are 82 ℔s per yard, and their average duration on the main line does not exceed four years, if so much, the traffic on each pair of rails being upwards of 120 trains per diem of goods, coal, and passengers. The great wear is not owing to wear of attrition, but to crushing, disintegration of the laminæ. The rails are double-headed, and worn out on both tables before they are taken out. The sleepers are three feet apart, and the rails are fixed in cast iron chairs with wooden keys, the joints being fished with long fishes and four bolts.

Iron rails are in their manufacture practically "scrap iron." They are formed of bars of various sections piled together and heated, and then rolled out. In the act of heating, the oxygen of the atmosphere gets access to their inner surfaces, and scale is formed. This scale does not roll out, but rolls in, keeping up a constant separation of fibres like the grain of wood. With a certain intensity of blow on the line, the chairs and sleepers serving as anvils, the fibres are crushed apart, and the utility of the rails is destroyed.

Steel rails are not formed of separate masses welded together, but each of a single ingot rolled out without flaw or imperfect junction. They are homogeneous, which the iron is not, and therefore do not disintegrate with the same amount of blow which disintegrates the iron. But to be safe, the steel rail requires to be not only homogeneous in metal, but in the temper of the metal also. If the steel rail be taken hot out of the rolls and thrown on a cold iron or stone floor, it may become partially chilled—hard and soft—and in this condition it is apt to break, for which reason it is always recommended to keep the steel rails as soft as possible, to prevent risk, in fact to reduce them to the condition of iron. But the better plan would be to use spring steel, and harden and temper it.

There is a notion prevailing that permanent way on cross sleepers is elastic by virtue of its discontinuous bearing. But it is obvious that if there be any yield of the rails between the supports, there is none at the chairs themselves. If the rail be loose in the chair, which it commonly is, and if the sleepers be loose in the concreted ballast, which they are commonly the looseness only serves to give momentum to the blows of the wheels, so that the rail drives into the chair, the chair drives into the sleeper, and the sleeper drives into the ballast, while the fish-joint bends at the weakest point.

On a portion of the main line of the North London, the rails and chairs being taken up, longitudinal timbers, four inches deep by eleven inches wide, were spiked down to the sleepers. On these longitudinals, midway between the sleepers, were placed cast iron brackets in which the rails were fixed, suspended by the upper table, and not resting on the lower table, as in chairs, the bottom of the rails being 1¼-inch above the longitudinal timber, so as not to touch it. The joints was fastened as usual. The cross sleepers were packed hard and tight on solid ballast. The longitudinal timbers were not packed, the result being that the rails were continuously supported on an elastic base. With the traffic of the trains the mechanical action was, that no wheel pressed directly on a single sleeper with a hard blow, but that the weight on each wheel was distributed over two or more sleepers, and that through an elastic medium. Practically, after nearly three years wear, none of these rails have been found to disintegrate, but are as perfect as when first laid down, except where connected rigidly to the ordinary line, and there the ends of the rails are split; and the elastic action is not merely vertical, but horizontal also, by a slight twist of the longitudinal timbers preventing side blows from the flanges of the wheels.

It was also found that the sleepers remained quite undisturbed in the ballast, owing to the distribution of the weight, and that they really became *sleepers*, instead of dancing up and down. Moreover, the provision for elastic action dispensed with the practice occasionally resorted to of digging up the ballast below the sleepers to soften it, and prevent the extreme rigidity. It is getting to be a known fact that constant traffic and the use of heavier engines and vehicles is gradually solidifying the whole of the railway lines, so that the destruction of the plant, both fixed and rolling, is on the increase. A superintendent of a long line running on hard ground informed the writer that he contemplated re-spacing the whole of his sleepers in order to use the softer intervals. An illustration of this great evil may be found in the fact that in the winter time when all the ground becomes hard with frost, the destruction of wheel tires and rails by breakage, is greatly on the increase.

After the successful result of the first experiment on elastic lines, the superintendent of permanent way, Mr. Matthews, laid down a second portion, in which the cross-sleepers are six feet apart, or double the ordinary distance, the supports of the rails on the longitudinals being three feet apart. The same result was obtained in preserving the sleepers steady in the ballast, though the elastic yielding was greatly increased, being quite perceptible under the rolling trains.

Ballast in England and elsewhere has become a kind of stereotyped custom on railways, though there are districts, as Egypt,—the Southern states of America—where a driver "guesses he never run on ballast but only on mud roads"—the Pampas of Buenos Ayres, the Llanos of Venezuela, and elsewhere, where no ballast can be had, and so it is dispensed with. But the theory of ballast has hardly been considered. It was originally used on non-porous soils, as a kind of easy drainage for surface water, and in some places tolerably cheap. And it does not yield like clay. But it very soon ceases to be porous under the sleeper, and becomes a kind of conglomerate, or concrete, each sleeper pit holding water like a pond. But inasmuch as it has been practically demonstrated that with a provision for elasticity the sleepers may advantageously be rigid fixtures, there seems to be no reason why the whole surface of a railway should be covered with 18 inches of gravel or broken stone, varying in price from 1s. to 2s. 6d. per cubic yard. The object should be rather to cover it with non-porous material, so as to keep out the surface water, the same principle on which we pave the footways of our streets; and there is no doubt that it would be cheaper in many cases to use stone flags or cast iron for sleepers, rigidly fixed and overlaid with elastic longitudinals, so as to dispense with ballast, even in first cost, say nothing of the saving in maintenance. As regards such lines as are constructed on brick arches, the elastic system would prevent the vibration which so commonly disintegrates them, and, by ramming down the ballast, forces out the parapets; and it would be better to cover the surface with non-porous material, such as paving stones, and get rid of mud and dust altogether. The action of this novel system depends upon the elasticity of the longitudinal timber, but inasmuch as there are circumstances in which timber is inadmissible, such as very hot climates, or climates of great heat and moisture combined or alternating, the writer was led to consider whether it might not be practicable to obtain the elasticity by the agency of metal. This can be done in two methods, substituting a broad T-iron for the longitudinal timber, or by applying springs of tempered steel beneath the seats of the rails, which in that case cannot be suspended by the upper table, but must rest below the vertical web, being supported between the bracket sides with provision for the small amount of movement required. Two models of cast sleepers are on the table, with elastic steel bases. The cost of them will not exceed ordinary iron way, as great weight of metal is saved.

It is desirable that the rails should be of such depth as not to deflect beneath the wheels, and also that they should not deflect laterally, for which reason the tables should be of ample width. It is also important that the rails should be so joined together as to form non-deflecting bars at the joints, though with provision for expansion and contraction. In examining the ordinary fishes it will be perceived that the original principles of the writer's invention have not been carried into effect. These fishes as ordinarily used, are parallel bars, about eighteen inches in length, and with four bolts to attach them to the rails. As the total depth of the fish is only between two-and-a-half to three inches, it is obvious that a pair of three inch bars cannot possibly be equivalent in strength to a rail five inches in depth, and provided with two broad tables. In order to compensate for this defect in some measure, the fishes are made as thick as possible, approaching an inch, making them very rigid. They are wedge-formed between the rail-tables, but at an obtuse angle, not an angle of repose, and they depend wholly on the bolts to keep them in position under the action of the trains, and the slightest movement of the rail loosens them. For this reason the bolts are made as large as possible. The large hole weakens the fishes, and it is necessary to drill the holes, as punching distorts a narrow thick bar. Moreover, as the fish is as thick at the ends as at the centre, the result is a blow from the wheel at the fish end, where it is too strong, and a second blow at the joint where it is too weak, and a gradual dent at the fish end into the rail, and another dent of the rail-end into the fish; and when these dents begin to form, the process of destruction is certain; rust is formed, rubbed off, and begins again, and the noise and jolt is rendered very perceptible to the passengers before the cause is detected by the eye, except when a train is passing, when the deflection is very perceptible.

To remedy this evil, the writer has devised a true form of fish. It is tapered from the ends towards the middle, where it is the full depth of the rail on the outside fish, and on the inner the full depth of the rail, less the upper table to make room for the wheel flanges. Angular ribs are rolled on the inside of the fishes, to fit accurately against the rail tables, and the fishes are arched laterally. The metal being thin, except at the ribs, they are easily punched without distortion, and when the bolts are screwed tight, the arches of the fishes flatten and press the ribs against the rail tables firmly. The bolts thus acting on elastic surfaces, the nuts remain tight, and the joint is elastically firm. The models of the elastic way, both in timber and iron, with steel springs, as well as the improved fish-joint, are on the table.

The writer has dwelt upon this subject the more earnestly because on any new plan connected with a railway, a protracted experiment is needed for verification, and this protracted experiment of elastic railway has been made, and can be examined by all who feel an interest in so important a subject.

(To be continued.)

For the Journal of the Franklin Institute.

Discussion of some Trussed Girders of one Arched Chord.

By S. W. Robinson, C. E.

This article, I intend to make a discussion—founded principally upon numerical results—of the economical arrangement of material in building trussed girders with one straight and one curved chord or stringer.

As iron comes into use for the construction of public works, it is very important, especially at present prices, to make that disposition of the material which shall result in securing the object sought with the least possible amount, for numerous reasons:—first and primary, *cost.*

There is no case where the cost of a structure can profitably be lost sight of by its projector. All modern bridges could have been built in the tubular form, of iron: a form possessing a desirable degree of rigidity and durability. The Niagara Suspension Bridge has established, beyond all doubt, the success of that form of bridging for both carriage- and rail-ways, though the construction of a tubular bridge in its place was a possibility. But the prospect of reducing cost ruled in the adoption of that form. And so in every case.

Of two or more methods of construction which will give equal satisfaction in every respect at varying costs, the minimum, if known, will prudently be chosen; and anything pointing this out should receive careful attention.

In the trussed girder of one bent chord, some of the principal points to be considered in respect to this are the depth of the truss near the middle compared with its length: the inclination of the tie rods in the panel trussing: and the form of the curve adopted for the arched chord.

The example I have selected for the basis of my numerical results is the same throughout, unless otherwise designated.

Let $2\,\text{B}$ = span = 160 feet.
a = depth of truss = 20 feet.
i = the angle of the tangent line to the curve of the arched chord, with the straight one, or with the axis X.

The loading one ton per foot along the roadway.

And of the two diagonals of a panel, let θ be the angle, reckoned from the straight chord, for that inclined toward the centre, θ^1 of that inclined from the centre; x and y co-ordinates to the curve of the chord.

The equation of the curve for the parabolic arc, origin at the crown, is

$$x^2 = \frac{\text{B}^2}{a}\,y. \quad \text{We also have } \frac{dy}{dx} = \frac{2\,a\,x}{\text{B}^2} = \text{tang } i,$$

$$y = \frac{\text{B}^2}{4\,a}\,\text{tang}^2 i, \quad \text{and tang } i = \frac{2\,a}{\text{B}}$$

making $x = \text{B}$, the point of junction of the chords; then for the given quantities,

$$\text{tang } i = \frac{40}{80} = 0{\cdot}5. \quad \text{Hence, } i^1 = 26^\circ\ 33'\ 54''.$$

Of the Depth of Truss.

Now, if we assume the weight of a cubic foot of the iron framework equal 450 pounds, and the weight of the diagonals, &c., equal $\frac{1}{8}$th of the arched chord, whose transverse section is K, and make the strains depend upon the weight of the frame together with that of the loading of 2000 pounds per foot in length of the truss; and take R = 20,000 pounds for the resistance of the iron per square inch of section; then I find for the section K,

for $a =$	26 feet.	K, 26·0 square inches.
“ “ “	35 “	“ 19·6 “ “
“ “ “	49 “	“ 13·0 “ “
“ $a =$ B $=$	80 “	“ 8·3 “ “

These figures show that the strains and the depth of the truss are nearly in an inverse proportion. But there is a limit in every practical case beyond which we should not attempt to pass. The change in the strains of the tie rods, &c., is small, compared with other changes by increasing the depth.

Of the system of inclined tie rods for the panel trussing of girders of one arched chord.

For an example, take the quantities given above, and let one of the curves adopted be the arc of a parabola of which the equation is also given: and $i = 26° \, 33' \, 54''$. Let there be 11 normals dividing the straight stringer into 12 parts, making 10 panels and 2 half panels. Divide i into 6 equal parts, and let the intersections of the normals with the curve be at points where the angle of the tangent to the curve is a multiple of $\frac{1}{6}i$. This causes the spaces to increase from the centre toward either end, but will answer for the present case. The strains I have computed are about the fourth panel from the middle, or third bay of the horizontal cord from the end.

I get $x_3 = 37{\cdot}77$, $y_3 = 4{\cdot}458$,

$x_4 = 51{\cdot}09$, $y_4 = 8{\cdot}158$,

$i_3 = 13° \, 16' \, 57''$, $i_4 = 17° \, 42' \, 36''$.

For the angle of the arched chord between the points $(x_3 \, y_3)$ and $(x_4 \, y_4)$.

$$\text{cotan}\, i' = \frac{x_4 - x_3}{y_4 - y_3} \quad \text{from which} \quad i' = 15° \, 31',$$

$$\text{and } \theta = 58° \, 28', \quad \theta' = 34° \, 53'.$$

For this panel the maximum stress of the arched chord, the truss loaded throughout and the diagonals acting as braces, is 165·2 tons. At this instant the strain of the brace of this panel is 6·0 tons.

Where the diagonals act as ties, the stress of the chord is 169·3 tons; and of the tie 5·4 tons.

For the *maximum* of the diagonal, the load extending from the remote end to this panel only; as a brace, is 15·9 tons. As a tie, 18·3 tons.

Now, if the normal tie rods be made vertical by swinging their lower ends, the maximum stress of the bent chord for this panel is 166·1 tons. The maximum of a diagonal as a brace is 20·5 tons; as a tie, 17·8 tons: and for a load throughout the truss the diagonals are relieved altogether.

The strains produced upon the diagonals when the loading extends throughout the whole structure and the tie rods normal, are compression upon those inclined from the centre, and tension upon those inclined towards it; while those which receive the maximum are the converse; that is, the maximum strains produced when the loading extends to the remote end; but the same when the loading extends to the near end, and this probably exceeds it.

The above figures show that no economy follows from inclining the tie rods when the diagonals act as ties, unless from the diminished stress of the straight chord, which at this panel is about 160 tons. But they perhaps show a slight gain when the diagonals act as braces, though the strain of the lower chord is then about 163 tons at this panel. This slight difference in our favor is mostly by reason of the thrust or pull of the diagonals when the bent chord has its maximum, which in one case is diminished and in the other increased. By this we would infer that if we adopt for the curve of the arched chord one of equilibrium for normal tie rods, or that which will cause the strains upon the diagonals to become zero when the maximum of the cord occurs, or when the load overreaches the whole truss, we may effect an advantage for the use of either ties or braces.

Curve of Equilibrium for Normal Tie Rods.

The new curve of equilibrium which I have investigated and given in the March number of the Journal for 1864, will be found to correspond exactly with the proposed curve.

The radius of curvature of this curve has its maximum* where that of the parabola is at its minimum, viz: at the apex or at the point corresponding to the crown of the arched chord. Also, for the parabola tang $i = \frac{1}{2}$, and in the equilibrated arc sin $i = \frac{1}{2}$ where the chords meet.

Now, if the origin and junction of the chords for both cases are at the same points, it is plain that the curve of equilibrium must lie entirely outside of the parabola between the points mentioned, the maximum departure, which, for the given example, is ·64 feet, being where a normal to each curve will become coincident with each other.

From this it follows, that for the new form we will have a greater depth of truss throughout except at the middle point. Therefore, we would naturally predict for this curve a diminished stress each way from the middle.

The properties of this curve, and its application to bridges, are discussed at some length in previous numbers of this Journal, where it is found that the stress is uniform and equal to that of the parabolic arc at the apex, or of any other curve where a and B are constant for all. In the June number for 1864 I gave the strains of the chords and diagonals for the same example as above. For the arched chord it was found to be 160 tons, and 160 tons at the middle of the straight stringer, which is less toward either end.

Among the results exhibited above we find none more favorable than those pertaining to the arc of equilibrium. Thus, to recapitulate, we have for the parabolic arc under the three conditions, 165·2, 169·3, and 166·1, while for the curve of equilibrium we have 160, or a saving of 5·2, 9·3, or 6·1 tons, and this at the fourth panel only, from the middle. These differences are still greater at the junction of the chords.

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* See March number for 1864.

Other Curves for the Arched Chord.

I have already observed that the radius of curvature increases for one, and diminishes for the other curve in passing from the origin. If, then, we adopt the curve having a constant radius of curvature, (the circle,) and the normal tie rods, we would approximate to the true form of curve, the curve of equilibrium. The circle, therefore, possesses advantages over the parabola as a form of curve for arched truss girders with normal tie rods.

The ellipse probably approximates still more closely to the true curve.

But for this, as well as for the circle, and even the parabola, when normals are introduced, the equations and formulas necessary to get the dimensions, and stresses of the parts, are much more complex than those for the arc of equilibrium, excepting, perhaps, the equations of the curves themselves.

For the Journal of the Franklin Institute.

Papers on Hydraulic Engineering. By SAMUEL McELROY, C. E.

No. 5.—*Fire Service and Hydrants.*

(Continued from page 92.)

Defects of Distribution.—Assuming entire adequacy in the fire department of a city, it is evident that the conditions of fire service, aside from the engines, require a proper reservoir head, distribution service, and hydrant arrangement, and cannot be otherwise correctly fulfilled.

In this, however, we except the process of engine supply by *cisterns*, to which some allusion is important in this connexion.

In cities which have grown to large proportions before the introduction of the Constant High Service, and depended on wells and pumps, it has been customary to construct large cisterns in the streets, for engine use. These have been supplied by rain-water, or by hand pumping from adjacent wells, and in some cases, after the introduction of water-mains, by special supply pipes. There are few large towns without these cisterns, some superseded and out of use, and others maintained for service.

In some cases, as at Boston, the deficiency in water head and hydrant calibre has led to their careful construction and maintenance as an important reserve. The Boston Report for 1864 refers to 15 such cisterns, which had been connected with the main pipes, making 96 in all; the Cleveland Report of April, 1862, refers to 49 cisterns, of which 27 had been connected with the mains; the Detroit Report for 1864 refers to 122 cisterns supplied by 3-inch valves and 5 by

4-inch valves, the necessity for increase in size being explained by the Report for 1861, which says:

> "Since the introduction of steam fire engines into the city, complaints have been made of the insufficiency of the supply of water in the street reservoirs in some localities; this may be remedied by introducing an additional stream into them."

The Report for 1854, p. 25, thus details the operations of these reservoirs:

> "In addition to the fire plugs, there are now sixty-five street reservoirs. * * * Twenty-one of these are supplied with water by a three-inch pipe, terminated with a valve. Early in the coming season, I hope to have them all supplied in the same manner. The old method of supplying them with wooden logs, terminated with plugs, was very insufficient, and caused a great deal of trouble and complaint. Upon examination, many of the logs are found to be connected with lead pipes of one inch diameter, and even some with pipes of five-eighths of an inch diameter. The logs in no case exceed a diameter of two inches. The consequence is, that two fire engines, worked constantly, will exhaust one of the reservoirs in from twenty to forty minutes, notwithstanding the plug is out and the water running. * * There is a further advantage in the use of a valve at the end of the pipe. The plug being almost invariably kicked into the reservoir on the occasion of its use, it is not likely to be recovered, and another is required to be furnished; and whenever it is replaced by driving it against the head of water, the operator is pretty sure of a good wetting. The valve being raised and lowered by means of a key, will prevent these inconveniences."

Without multiplying these instances, we may refer to a case, where no hydrants are in use. The Louisville Report for 1861 says:

> "One hundred of the street cisterns for the Fire Department are connected with the water pipes. No fire-plugs are in use, their efficacy for supplying steam fire engines with water has heretofore been regarded as doubtful. In some of the Eastern cities they are, however, used in addition to street cisterns, and regarded as equally efficacious, and much more economical in construction and the use of water, from the fact that cisterns, as generally constructed, are frequently leaky, and particularly so in streets where there is much heavy traffic, subjecting the cisterns to violent jarring and consequent leaks. It is believed that fire-plugs, properly constructed, can be introduced with advantage to the steam fire engines and great economy in the use of water, especially along the 6, 8, and 10-inch lines of pipe."

While these extracts embody a sufficient condemnation of the class of fire-hydrants in common use, as entirely insufficient for their special work, they also embody a sufficient summary of objections to the use of cisterns, viz.: a cost which limits them to wide intervals of position and prevents their service for large fires; a limited capacity while in service; a want of durability; and an additional load on fire-engine pumps by the necessary suction lift, as contrasted with the relief of reservoir head, through a proper hydrant connexion; they are also out of question for the first process of fire-service, which is independent of engines.

In connexion with the subject of distribution, the following table is given, as embodying some of its leading characteristics in practice.

Distribution Statistics.

LOCALITY.	Year.	Population 1860.	Houses supplied.	Reservoir Level.	Distributing Mains.	Fire Hydrants.			Stop-cocks.	Public Cisterns.
					Miles.	Intervals.	Number.	Repaired.		
Albany,	1863	62,368		156·245	49·36	feet. 976	267		167	
Baltimore,	1861	212,419	16,915	150	136·00	1253	573	74	656	
Boston,	1861 1864	177,481	24,720	123·5	131·30 136 60	 471	1451 1530	199 94	1188 1312	24 96
Bridgeport,	1853			115	15·00		20			
Brooklyn,	1863	266,664	taps. 17,145	172·197	164·53	711	1220	378	968	
Buffalo,	1859	81,131		88	32·00					
Chicago,	1862 1864	109,263		85	95·30 117·90	 1135	469 548	55	221 298	
Cincinnati,	1862	161,044	taps. 13,333	175	88·40					
Cleveland,	1861–2 1863–4	136,054		160	24·38 27·32	912	142 158		285 325	49 48
Detroit,	1862 1864	45,619	7,275	77·5	68·00 72·60	1539	240 249	17 12	295 312	124 127
Elizabeth,	1858			60	7·00		50			
Hartford,	1862	29,152		121	29·08	1030	149		180	
Jersey City,	1861–2	29,226		124·5	39·65	656	315		262	
Louisville,	1863	69,470	1,211	150	32 26		none.			124
New Britain,	1859			175	10·00		16			
New York,	1863	814,287	60,000	114	290·48	586	2615		ab't 2200	
Philadelphia,	1862 1864	568,034	76,299	98·124	346·12 363·80	 538	3055 3255		3779 3967	
Washington,	1863	61,122		145	17·35					

Reservoirs under the Constant High Service, or their equivalent stand-pipes, are rarely open to the objection of an insufficient head to control the highest buildings of their district. Care is generally taken in this direction by hydraulic engineers, and reservoir sites are determined with regard to the highest planes of the supply district. In many cases the head is excessive for the great majority of buildings supplied, being arranged for the use of smaller and more elevated planes, and instances occur of two or more reservoirs at different levels so connected in their district supply mains, as to make the highest available for the lower levels.

In London, with an Intermittent Service, the hydraulic heads range from 82 to 120, 157, 185, 207·5, 350 and 430 feet above Trinity datum, 120 feet being sufficient for the city proper; at Glasgow the Gorbals Gravitation head is 225; the Kilmarnock 270, and the Stirling 450 feet; the heads at Detroit and Fairmount are low, 77·5 in the first case and 98 in the second, but their districts are peculiar; the head at New York is 114 feet, at Boston 123·5, at Hartford 121 feet, at Cleveland and at Louisville 150 feet, at Jersey City 158 feet, at Brooklyn

172 and 197 feet, at Albany 156 and 245 feet, at Watertown 245 feet; in these and other cases, the blame for defects in power of supply cannot be charged to want of controlling elevations, although some such instances are presented in the foregoing table.

With the care usually bestowed on reservoir location, it is strange that an equally important branch of the supply should either be overlooked in its details as a subordinate matter, or intentionally restricted, from mistaken ideas of economy, or from a desire to keep within certain general estimates of cost, by retrenching at the points usually last completed. For these, or similarly inexcusable reasons, it follows that distribution services, as a rule, are so imperfectly planned or laid, as to vitiate much of the benefit secured at the reservoir, and to grow worse and worse with increasing city consumption and increasing extensions of service mains.

The resultant evils of restricted head and delivery are due to inadequate *feeding mains*, in number, size and location, and to inadequate *service mains* in size, and also, in process of time, to the growth of tubercles wherever cast iron pipes are used.

Illustrations of this principle abound, and in most cases with aggravated circumstances. Water works which rival Roman Aqueducts in extent and cost, come far short of their true mission, when tried by lapse of time, and are eked out in service by hundreds of private engines at immense aggregate annual cost; works which boasted an hydraulic power able to supersede all fire engines and drive numerous factories and machine shops, are put to shame by the first " steamer" which connects with a fire-hydrant and has to put on its suction; the country abounds in extravagant aqueducts, engine houses, engines and reservoirs with appended systems of mains, which vitiate the greater part of the expended capital, and keep the element of health and safety almost out of reach; the city of New York with its investment of over twenty millions in supply, below Fourteenth Street and in the busiest region, is virtually exhausted, with a practical head at Canal Street, of not more than 60 feet above tide, as long ago as 1858; the City of Boston, with its superb Beacon hill reservoir in the very heart of its compactness, in twelve brief years, lapses towards the *cisternæ* of ancient times; good old, square blocked Philadelphia is ingenious in turning hydrants into suction-tubes; Hartford, spending $57,000 on her fancy engine house, cannot supply her charitable asylums; Louisville has $31,286 for a questionable stand-pipe, but no money for fire-hydrants; Detroit since 1857 has laid 77,498 feet of 2½ and 3 inch wood logs: Brooklyn, not yet relieved of her Construction Board, has already reduced her lines of eight inch mains to less than seven, and after a large outlay for protection vanishes, finds that four years at the furthest, is the limit of palliation from the tubercles; from such chapters of experiences, as matter of daily record these many years, one is taught what to avoid and what to improve.

Experimental illustrations of serious differences in effect in service mains or fire hose have abounded in practice, but do not abound in records of practice, as these are by no means voluminous. In one case given in a Parliamentary Report, a $2\frac{1}{2}$-inch stand-pipe attached London fashion, directly to the street main, gave, from a 9-inch main 7200 feet long, connected to 3000 feet of 15-inch, under a fixed head of 120 feet, through 40 feet of hose and a $\frac{7}{8}$-inch nozzle, a jet 60 feet high; the same appurtenances, on a 7-inch main of 2400 feet, from 1500 feet of 9 inch and 600 feet of 12 inch, connected with 1650 feet of 15-inch main, under the same head, gave a 50 feet jet; while the jet from 600 feet of 4-inch main, with 600 feet of 5-inch, from the 9-inch main first mentioned, was 34 feet high. The aggregate length in the first case was 10,200 feet, and in the second 6150, and in the third 11,400, and between the first and third an additional length of 1200 feet, or not quite 12 per cent. reduced the jet from 60 to 34 feet, or over 43 per cent. the stand-pipe and hose friction being less in the third case than in the first, from diminished delivery. When it is remembered that a 9-inch pipe has not only about five times the calibre, but with the same hydraulic inclination, has nearly twice the velocity of a 5-inch, it is readily understood that calibre is an important item in maintenance of head on the attachment of street mains. As a farther illustration of the value of large feeding mains, we may cite an experiment on the 20-inch main at the Prospect Hill Engine House, in Brooklyn, in May, 1862.

Here the engine takes its supply from a 20 inch main of 1600 feet, leading from a 30-inch main of 3000 feet, and a 36-inch main of 26,062 feet, all being used directly for distribution except 15,637 feet of the latter which connects with Ridgewood Reservoir. With the engine pumping 3,750,000 gallons per day, and a rate of daily city draft* of not less than 9,250,000 gallons in addition, the dynamic head at 10 A. M. was 122 feet, (or about 42 feet frictional loss) taking the Reservoir at 164 feet. The maximum loss of head, for 5·8 miles of pipe, was about 25 per cent. at the time of greatest city draft.

This experiment, however, does not correctly indicate the dynamic head on the general service mains at the time, since the gauge was placed on the main at a point where it was itself feeding at the rate of 3,750,000 gallons per day, or more than one-quarter the entire reservoir delivery at the time. The gauge stood at 22 ℔s, or 7·5 feet below the reservoir, before the engine started, and at 18 ℔s or 16·5 feet below, at 11 P. M., with the engine at its regular work, but the city drawing only 10 per cent. of its demand at 9 A. M.

The office gauge in Halsey's Building, Jan. 24, 1865, at 10 A. M., stood at 21 lbs., with the pipe at rest, which is a $\frac{3}{8}$ connexion with the street main of 8-inch calibre and about 80 feet in length. On opening its discharge it fell to $12\frac{1}{2}$ lbs. with its current established; closing it, the index returned to 23 lbs. showing more correctly the street main head. As the gauge stands 83·5 feet above tide, the service main head was not less than 136·5 feet or 33·5 feet below the reservoir reported at 170 feet, or about 20 per cent. friction, the city draft being estimated at 8,500,000 average per day, which would give a rate of 17,000,000 at the time. If we take the frequent gauge reading of 16 lbs. as the more correct index of this draft, the loss of head will be 45 feet or 26½ per cent.

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*This estimate of city draft at 10, A. M., is based on a statement in the Report for 1862, that "more than nine-tenths of the daily consumption is in the twelve hours from 5 A. M. to 5 P. M.," which is not confirmed by experience in other cities.

One of the 6-inch jets of the Boston Common fountain in 1853, rose 90 feet above tide, its reservoir having a flow line of 120 feet; at this time however the city draft was slight, and the fountain is not very far from Beacon Hill.

From these and similar examples, two deductions may be made; first, that it is possible to maintain an extended distribution service from a distant reservoir, with a head within 30 per cent. of the starting point, and that as the demand increases, additional feeders will promply meet it; and second, that it is equally possible to vitiate more than 50 or 60 per cent. of the head by a defective service arrangement. The proper correctives are therefore clearly indicated.

The defects in this direction are to be traced to want of care in the arrangement of what are too often considered subordinate details; the most ample supply of water may have been secured, and there may be a superabundant reservoir head; it rarely happens with us, that these features are deficient; but if the distribution service is badly arranged as to feeding mains and calibre of service mains; if the hydrant branches are too small; if excessive friction occurs in hydrant tubes; if the hydrants are out of order; if long lines of hose are needed, because of improper intervals between hydrants, it is easy to comprehend why it happens so often in the history of burning buildings, that the losses of a single fire may far exceed all the expense attempted to be saved by such short-sighted and inadequate arrangements. What is true in the annals of conflagrations, in many of our prominent cities, as at New York in 1835, Albany in 1849, Troy in 1863, and other similar cases, (of neglect of proper supply) is true also, on a smaller scale, of neglect of proper arrangement; such parsimony being the very opposite to true economy.

Progress of Fire-Hydrants.—Having considered the objects and methods of distribution, the progress of fire engines, the conditions of fire service, and some of the defects of the present system, we come now to the progress made in hydrants and attachments.

From what has been said of the method of water delivery under the Low Service, as in general practice among the ancients, and the method of engine supply, it is easy to understand why the fire-hydrant, as we have it, is an attachment of recent date.

Matthews refers, in 1835, to the improved fire-service of London, and the use of fire-plugs, as follows:

> "Whenever, or wherever, such calamities occur, a great abundance of water is almost instantly afforded, by means of the simple contrivance of pulling up the plugs connected with the principal mains, and thus the firemen are enabled to supply their engines, without intermission, either to prevent conflagrations from extending their ravages, or effectually to extinguish them."

The plugs thus described are illustrated by a plate, which represents a conical plug seat cast on the water main, into which a plug is fitted, carrying a short handle, and surrounded with a wooden case, flush with the street pavement. No hose-nozzle is shown, and as the suction engines were in use in the previous century, the suction tube was probably dropped into the casing tube and was thus supplied, when the plug was drawn out; a process barely admissible with a low head, and inadmissible with high service. Since that time hydrants of various forms have been introduced, in some cases on the curb-line, as attachments to gas posts, but more generally as upright stand-pipes from the mains, with a turn-cock, and with a hose-nozzle, flush with the pavement. Under the Constant High Service of Hamburgh, the hydrant tube is attached to the side of the street main, so as to take a stop-cock, worked by a vertical rod from the street, the discharge pipe, 3 inches diameter in the clear, being curved up to street grade, where it ends in a nozzle-box, generally fitted with a two-way branch. At Glasgow, under a head of 225 to 450 feet, a hydrant is in use, as a stand-pipe terminating in a head with four nozzles, from which four lines of hose may be operated. This use of stand-pipes connected directly with the mains, and usually of 2½-inch calibre, is peculiar to European water works, under the Constant Service, and belongs to the class of contracted "flush" hydrants.

The operation of the common English fire-plug is thus described in 1850, in the Report of the General Board of Health:

> "With the ordinary plug it is necessary, on the discovery of a fire, to seek the turn cock, who is obliged, if the mains are full and a constant supply given, to seek the nearest main tap and turn off the water until the fire-plug is opened and the hose attached, and then go back and turn it on again. In the midst of the confusion much valuable time is thus added to that already lost in procuring the engines."

The original form of fire-hydrant under constant head in this country, may be traced to the year 1803, at Philadelphia, in a city which has the credit of being a pioneer in perfected water supply, and a pattern to all the rest. For this rank, Philadelphia is chiefly indebted to two men of genius, Benjamin Franklin, the philosopher, who advised, and Frederick Graff, the engineer, who planned and completed the noble work.

Although other and recent water works have taken a higher rank in scale of supply, this engineer must always be conceded the foremost place on the records of professional fame in hydraulic engineering, since his genius enabled him to put the Fairmount works far in advance of their European cotemporaries, in general design and perfection of detail, whether we examine the pumping machinery, the reservoirs, the arrangement of distribution service, or the details of water delivery. The studied arrangement of the pump-rooms with regard to future extension and lavish delivery; the subdivision of the reservoirs and their careful construction; and the abandonment of the niggardly policy of the European examples; the prompt substitution of cast iron mains; the general use of street washers, with hydrant pumps and other conveniences for city and individual comfort; and the use of hydrants, with hose nozzles, for engine supply or direct fire supply, under constant head, characterize, in each department, a genius ahead of its age, of whose forethought those who follow after have not been slow to avail themselves. Listening to the cooling and lulling plash of the fountain in the beautiful grove on the banks of the Schuylkill, some quiet sunset hour, and studying the "wave theory" in the regular pulsations of its branching jets, one may well understand that an arduous professional life, as a labor of beneficence to others, may be full of its own rewards, and leaves a better and more enduring record than princely titles or gold-bought epitaphs.

The fire-hydrant referred to in the water laws of Philadelphia of 1806, is illustrated by an engraving published Oct. 1, 1817, "for the use of Hose and Engine Companies." This shows a cast iron hydrant, inserted by a tapering joint into a wooden main. The case was not shown, but was evidently used from the accounts paid for straw to pack it for the winter. The valve seat is placed at the base of the hydrant near the upper surface of the main. The valve drops in opening and is worked by a rod passing through the centre of the tube, with a stuffing box, saddle, screw-shaft, and handle mainly as in present use; the diameter of the tube is *larger* than that of the main by the diameter of the rod. The hose nozzle is fitted as a female screw. The frost vent is fitted near the valve-seat with a right-angle elbow, so that a plug-rod worked by hand may be raised from its mouth when the valve is shut, and frees the tube down to the main.

The Philadelphia fire-hydrant as illustrated Jan. 15, 1854, for the use of the Fire Department, is of similar type with that of 1806, except that it has a hydrant bend from the branch main, into which its base is leaded and held by a clamp collar and lugs, and that the frost rod is worked by the screw-shaft in place of by hand. It has these objections,—that the valve seat is thrown about 14 inches nearer the pavement grade, and that the frost vent, does not free the tube, as low as the valve-seat, or as low by 13 inches as the older form; with a branch calibre of 4 inches, the valve opening is also but 2½. In both cases the hydrants have "stand-pipe" heads projecting about two feet above the pavement, the centre of the hose nozzle being about six inches above.

Recently an improvement has been made in the calibre of the Philadelphia hydrants, and in the addition of an air-chamber, to meet the requirements and modify the action of the steam fire-engines, as will be more particularly noticed under the special head of "calibre."

A form of main hydrant recently introduced at street corners in Brooklyn, with a tube of large calibre, has a puppet valve fitting a seat on the main, or a short casting introduced in the main line, which is worked by a centre-rod and terminates in a "flush" head carrying several hose-nozzles.

This general form of the Philadelphia hydrant of 1854, may be taken as an index of all others in common use, as to the use of a case, the internal valve motion, and the use of a frost vent, a hydrant bend between the branch and the tube, and a branch pipe from the main to the sidewalk. There are differences in detail, peculiar to different localities, of which a special analysis will be made in the following chapter on contingencies and defects.

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On the relative advantages of the Inch and the Metre as the Standard Unit of Decimal Measure. By Mr. JOHN FERNIE, of Leeds.

From the London Mechanics' Magazine, February, 1865.

The subject of a decimal system of measure resolves itself into two parts—the desirability of a decimal system, and the standard of measure to be adopted as the unit; the first of which may now be considered settled, and the principle definitely adopted in this country, the use of decimal measures being now legalized by a recent Act of Parliament. But the second part of the subject, the standard of measure, is still open, and is of very great importance; the consideration of it involves two preliminary scientific questions, and two practical conditions to be fulfilled.

In respect of the first scientific question—as to the standard that can be replaced best in case of being lost—there is no real choice between the metre and the inch: for the metre having been originally determined by measuring part of a quadrant of the earth's circumference, its length was also referred to the seconds pendulum for facility of repeating the measurement; and the inch being obtained from the seconds pendulum both the metre and the inch are thus verified by the same means; indeed the relation between them being once established, any means of verification is equally available for both. In regard to the second scientific question—as to the standard that is most universal in the character of its basis—the supposed advantage of the metre, as an even fraction of the quadrant, has been proved by the results of more accurate measurement to be a mistake, its actual length being an uneven fraction of the quadrant, just as the inch is an uneven fraction of the pendulum; and the length of the quadrant itself being different in different longitudes, there is therefore no choice between the metre and the inch, in respect of universality of its basis. The present legal standard of measure in this country is an individual metallic yard measure, independent of any reference to another source; and the metre is similarly a continuation or copy of an original standard metre which is now known to differ from the exact measure that it was intended to represent of the quadrant. There is no practical disadvantage, however, as regards accuracy in depending upon copying for the preservation of a standard; for by Mr. Whitworth's process of contact measurement, the accuracy in copying lengths can now be carried as far as one millionth of an inch, which is a higher approximation than can yet be attained in measuring the length of a pendulum or an arc of the earth's circumference.

The first practical condition to be fulfilled by the standard of measure is that it shall be the one best suited for use in decimal subdivision; and this point is to be determined by the relative practical convenience or inconvenience of its principal subdivisions and multiples. In connexion with mechanical engineering work, the inch has a special qualification for the standard of measure, since its subdivisions and multiples predominate in the dimensions of the parts of machinery; it is the basis on which the various machines and engines made in this country have been constructed, and on which are founded calculations of strength of materials, sectional areas, steam pressure, power, velocity, capacity, and weight; so that the mechanical engineer may be said to think in inches, calculate in inches, and work in inches. For the classes of work in which the finer measurements are required, such as rifle bores, wire and metal gauges, &c., the desired degree of accuracy is readily and conveniently expressed in thousandths of an inch; whilst the millimetre, the smallest subdivision of the metre scale, not being smaller than 1-26th of an inch, requires the addition of two places of decimals to give the same degree of accuracy. This is a practical advantage of importance in favor of the inch as the unit of measure, since dimensions to one-thousandths of an inch are now required in regular use in mechanical work. Moreover, by taking as the unit the lowest of the present denominations—the inch—any longer dimensions on the present scale can be exactly expressed in the decimal system without fractional remainders. The second practical condition attaching to the standard of measure is that it shall be the one most extensively in use already, so as to involve the least alteration of existing measures; and in addition to a preponderance in the population now using the inch over that now using the metre, the former includes the great machinery producers, whose work already exists in such large quantities in all parts of the world in the form of engines, machinery, railway plant and tools; and the difficulties in the way of a change to the metre in this country appear, therefore, so insuperable as to amount practically to a prohibition of a decimal system, if it is to be based on the metre.

The general conclusions submitted in the paper in reference to the standard for decimal measure are, that, whilst the inch and the metre are equally eligible as regards their basis of reference, and could be replaced with equal accuracy in the event of being lost, the metre is not suitable for adoption in this country on account of its entire difference from the existing measures; and the inch is the most suitable standard of measure, from the extent to which it is involved in mechanical work, and from its convenience for expressing the smaller dimensions extensively used. For larger dimensions the most convenient decimal change would be the adoption of a 10-inch foot; and the larger measures being already multiples of the inch, their decimal adaptation to the inch would be at least easier than their entire alteration to the metre standard. It is also very desirable that the present weights and measures of capacity should be reduced to decimal systems; and it is considered that they can practically be based as readily upon the inch as the standard of measure as upon the metre, in the same way as with the definition of the metre or the inch.

In the discussion which followed the reading of this paper, the metre as the standard unit of decimal measure, in preference to the inch, was advocated by a deputation from the International Decimal Association, who concurred in considering that the question of the standard of measure depended upon the fulfilment of the practical conditions which had been stated; that the standard should be the one best suited for use in decimal subdivision, and the one most extensively adopted already. As regarded decimal subdivision, the results of inquiries made by the Association had led them to recommend the metre as adapted for the greatest variety of measurements, and for the most numerous cases likely to occur in daily life; and to conclude that the inch did not in itself offer any advantage above the metre, even to mechanical engineers, since accuracy of measurement depended not on the scale, but on the measuring instrument employed, which ought to be applicable to any scale: and the millimetre had been already tried to some extent in this country, and was found convenient and suitable for mechanical work. In reference to the extent of population adopting the metre or the inch, it was believed that the numerical preponderance was already in favor of the former, and was steadily increasing by the more general adoption of the metre in other countries; and the simplicity and convenience of the metre system, both for measures and weights, were urged, together with the great importance of facilitating international communications, which were now so much interfered with by the incongruity of the systems in use.

The meeting then terminated. In the evening a number of the members and their friends dined together, in celebration of the 18th anniversary of the Institution.

On the reduction of Aluminium by Zinc.

From the London Mechanics' Magazine, January, 1865.

Aluminium would seem to be on the point of being very considerably cheapened. The largest item of its cost hitherto has been that of the sodium used for its reduction, but we are now told that M. Basset, of Paris, has succeeded in reducing it from its chloride by means of the very much cheaper metal, zinc. The idea of using zinc to reduce aluminium is not at all new—it was patented in this country, as a communication from abroad, as far back as 1854, but no one before M. Basset ever succeeded in practically realizing it. M. Basset's plan is to fuse chloride of aluminium with an *excess* of zinc, and he states that the results are chloride of zinc and an alloy of zinc and aluminium from which all the zinc may be driven off by a white heat. If this process be really practicable on the great scale, there will be no reason why aluminium should not speedily become cheap enough for employment in the many mechanical applications for which it is so admirably fitted, instead of being confined, as at present, to ornamental uses only.

There are other metals than aluminium in respect of which zinc seems likely to prove useful as a reducing agent. Last spring M. Poumarede forwarded to the Academy of Sciences of Paris, a communication respecting the use of its vapor as a means of reducing the more difficultly reducible of the heavy metals, as chromium, cobalt, nickle, and manganese. He stated that it reduces all these metals, especially from their chlorides or fluorides, quite easily, and we have recently seen his experiments repeated in London with the fullest success.

Description of a Cheap Form of Automatic Regulator of the Electric Light. By Mr. Samuel Highly.

From the London Athenæum, Oct., 1864.

The principle of this "Pneumatic Electric Regulator" was suggested to the author by Mr. Malden. The instrument is sensitive in action, and, from its simplicity, little liable to get out of order, and can be arranged for any length of carbon. The rod supporting the upper carbon is attached to a copper float, which rests upon a column of water, contained in a chamber communicating by an opening with an air chamber, from which a pipe, terminated by a flexible tube of vulcanized rubber, is carried under a wedged-shaped piece attached to the rod holding the lower carbon, and which passes through a stout coil of insulated wire. When the carbons are brought into contact the current passes through, and the coil becomes magnetic, pulls down the iron core, and separates the carbon, so as to produce the proper arc of light; at the same time forcing down the wedge upon the flexible tube, closing it as effectually as with a stop-cock. As soon as the distance between the poles becomes too great for the current to pass freely, the coil ceases to be magnetic, and the lower rod is raised slightly by means of a lever and counterpoise spring. Air is thus forced from the chamber by the column of water; the float sinks, bringing down the upper carbon into contact with the lower one; the current is thus again completed; the coil becomes magnetic, and pulls down the iron core, pressing the stop-cock wedge upon the upper tube. These operations are repeated sympathetically as the carbon burns away.

The Magnesian Light.

From the Lond. Civ. Eng. and Arch. Journal, Jan., 1865.

A lamp for the purpose of burning the wire is said to have been invented by Mr. A. Grant, who is endeavoring to bring his design to practical perfection. Mr. Grant seeks to make magnesium cheaper still than the best stearine, and states that by burning a strip of zinc in conjunction with two strips of magnesium he is able to reduce the cost of the light by two-thirds. He even ventures to predict that magnesium will become as cheap as zinc, and that in the course of time it will be possible to illuminate a street a mile long, at the rate of half-penny per hour! It is not a small thing to be able to record that photography is no longer dependent upon the action of the sun. The value of magnesium as an illuminator for the purpose of "signaling," is too obvious to escape immediate recognition. The portable nature of the contrivance, and its perfect immunity from risk of explosion, together with some other evident advantages, render its vivid light all the more practically valuable. The Parisians, we are told, are going to make it figure on the stage, and have sent orders for some of Mr. Grant's lamps to illuminate their painted scenery.

A New Blasting Gunpowder. By M. H. Schwartz.

From the London Chemical News, 267.

This powder is now largely employed in mining. Its combustion is slow, but complete. The following analyses show why it is cheaper than ordinary powder :

	I.	II.
Soluble salts,	74·55	74·32
Nitrate of potash,	56·22	56·23
Nitrate of soda,	18·30	18·09

The treatment by sulphide of carbon produced :—

Dissolved sulphur,	9·68	7·61
Carbon remaining,	14·14	15·01
Moisture,	1·78	11

It is a coarse-grained powder, in which one part of potash nitre is replaced by nitrate of soda.

In the first instance, one part of nitrate of soda for one part of nitrate of potash was used, but it was afterwards found best to employ a third of nitrate of soda.—*Bulletin de la Société Chimique.*

On Joule's Method of Testing Steam Boilers by Hydraulic Pressure.

From Newton's London Journal of Arts, March, 1865.

The President drew attention to the late fatal explosion at Peterborough, and asked whether the easy method of testing steam boilers, described some years ago by Dr. Joule, was forgotten, or found to be impracticable?

Dr. Joule said, that he had taken pains to give his method—by which the testing by hydraulic pressure could be applied with the utmost facility, by simply filling the boiler with water, and then raising its temperature a few degrees—a very extended publication. He believed that the objection raised by some to its use, was the absurd one that hydraulic pressure injured the boiler. The very object of a test was to detect weak boilers, for the purpose of strengthening or rejecting them. He was at a loss for terms strong enough to express his opinion of the reckless disregard of life, or the ignorance which resulted in the deplorable catastrophes which were constantly occurring; and he believed that the only method of cure would be that proposed by Mr. Binney, in the case of the explosion of fire-damp in mines, namely, that the parties to blame should be compelled to support the widows and orphans of their victims.

Mr. Alderman Pochin stated that he had made use of Dr. Joule's plan, and found it quite practicable and easy of application.

Proc. Manchester Liter. and Philos. Soc. Feb. 7, 1865.

For the Journal of the Franklin Institute.

On Work and Vis-viva. By J. W. Nystrom, Act. Chf. Eng., U. S. N.

In a previous article on Physical Work, a continuance of the same subject was promised, extending to the combined action of gravity and mechanical force, the manuscript of which has since been lying on the shelf, awaiting some criticisms on the part already published.

In the great confusion which now involves the subject, it was deemed necessary to advance cautiously, having each step of progress thoroughly discussed as far as it went; for experience admonishes us, that any reform, however simple or important, cannot be introduced and accepted without due deliberation.

The liberal criticisms of Prof. De Volson Wood, however much at variance in doctrine with my own, were perused with unaffected satisfaction, and should the interest in the subject evinced by him be followed by others, we might hope that valuable light would ultimately be shed upon it.

The greater part of his criticism is derived from misconception of the meaning of the letter V. In work ($W = F V T$), V means the velocity of the force F; or if F and V either, or both, are variable, then they can only signify the *mean* force, and *mean* velocity in the time T. In the member $M V^2$, V means the uniform velocity of the moving body M, after the force F has ceased to act upon it; or the final velocity imparted to the body M by the force F at the time T.

Prof. Wood says, "*the member* $F V T$ *does not express the work which the force* F *does upon a body free to move, in producing the velocity* V *in time* T*; but when the body is free to move, as here supposed, it equals one-half the work.*" In this he is in error. $F V T$ equals twice the work when V means the final velocity of the constant force F at the time T, because the *final* velocity of the force F is just twice its *mean* velocity in the time T, as will be proved hereafter.

Prof. W. says. "*If still further we admit that* $F T = S$ *and* $V^2 = 2 g S$, *we have by substitution and reduction,* $F = 2 W$ *which cannot be true.*" This is most probably a misprint, and Prof. Wood means $F V = S$, in which case V must be the *mean* or uniform velocity in the space S; but in the formula $V^2 = 2 g S$, V means the *final* velocity in the space S, which reduces $F = W$, which *is* true. Prof. Wood by W means weight. He says "*We see then that the equation* $F V T = M V^2$ *reduces to an absurdity under every hypothesis except the first, and in that, it simply gives a true equation without expressing the value of work.*" Is it possible that the formula can be a true equation of work without expressing the value of work? It gives precisely the same value of work as *vis-viva*; still he says; "*We see then that it never expresses the true relation between work and vis-viva.*" I contend that it does, and shall proceed to prove it in this article.

If I am not very much mistaken, Prof. Wood is confused in his conception of *force, power*, and *work*. He says that "*work was called by Smeaton, Mechanical Power, and by Monge and others Dynamic*

Effect." I understand those authors to mean F V for mechanical power and dynamic effect, and not F S, which is work, and regret that I have not succeeded in making Prof. W. understand the difference between power and work, and that F V T is work. He admits that $S = V\,T$, when V is constant; he also admits that work is F S; will he then not allow us to insert V T for S in work, which will make F V T? Professor Wood further says "*Now the work alone in the space* S, *is the same, whether it be done in one hour, day, or week; it is independent of the time.*" Then he confounds horse-power with work, in which he says time *is* included! This radical error has been persistently maintained in antagonism to me by Professors and Engineers, from a date long antecedent to my article on Work as published in this *Journal*; and Professor Wood will have no difficulty in finding supporters in that doctrine, for as accepted by him it is taught in schools and colleges. I have in the last eight months had frequent occasion to discuss the subject with Engineers, some of whom were apparently fresh from college and have studied *Weisebach's, Bartlett's and Moseley's Mechanics*; and who not only differ with me on the subject, but also disagree amongst themselves. They all seem to agree that *time is not* included in work, and the few who acknowledge the existence of power as a different quantity from work, also agree that time is included in power, but not in work. They argue that "the unit of power is 33,000 pounds lifted one foot per minute, whilst work is one pound lifted one foot independently of the time." They also assert that space is a simple element, and that velocity is a compound result of time and space.

My argument on the contrary is this; that the space one foot is the product of *time* and *velocity*, and when we say "*per time*, in the unit of *power*, we divide the space by the time, and the remainder is only pounds and velocity. Therefore in the ordinary conception of work F S, the *time* and *velocity* are included in the space S.

Let F = weight or force in pounds; v = velocity in feet per second of the force F, t = time in seconds; F and V being constant or the mean in the time t, S = space in feet traversed by the force F; P = power expressed in foot-pounds of power; W = work in foot-pounds of work.

The popular expression of power is

$$P = \frac{FS}{T}, \text{ but when } S = vt,$$

$$\text{we have } P = \frac{Fvt}{t} = Fv, \text{ the primitive formula for power.}$$

The popular expression of work is,

$$W = FS, \text{ but when } S = vt,$$

$$\text{we have } W = Fvt, \text{ the primitive formula for work.}$$

These are the fundamental formulas throughout the science of dynamics. They include the whole conglomeration of *Vis-viva*, the different momentum and quantities of motion, activity, inertia, energy, dynamic effects, &c., &c., as shall hereafter be proved.

It is perfectly absurd to say with Prof. Wood and others, "*that work is independent of time.*" If that were so, why then is *time* such an important item in contracts for work? and why do we so often fail to accomplish a contracted work in a specified time? In digging a canal, the power in operation, $P = Fv$, is represented by the number of laborers, and the quantity of work accomplished will be direct as the time. Prof. Wood may do a work in one minute, in one day, or in any time he pleases, the work accomplished will, in all cases, be Fvt, and nothing else. For a given quantity of work, *time* can vary, only at the expense of force or velocity. On Prof. Wood's reasoning we can say that force is independent of work, because a force of one pound can accomplish as much work as a force of 100 pounds; but at the expense of time and velocity only. Cannot the Professor understand and admit, that space cannot be accomplished without time and velocity? He may easily satisfy himself in simple experiments by drawing chalk-lines on the black-board.

Prof. W. maintains that "*the English unit of work is* 33,000 *pounds raised one foot per minute.*" This is the English unit for power, and not as he erroneously assumes, for work.

Power is the rate at which work is executed.

Power is working or labor, and the result of labor is work.

Power is the differential of work.

Work is the integral of power.

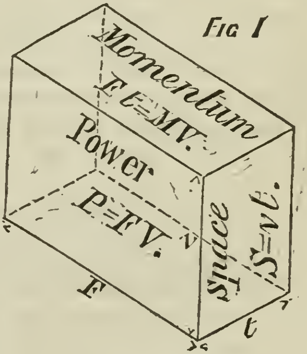


Fig I

The subject may be better illustrated as follows:

The three dimensions, *length*, *breadth* and *thickness* in this parallelopipedon, may be assumed to represent the elements *force* F, *velocity* v, *and time* t. The area of the side elevation Fv, therefore represents the power. The area of the end elevation vt represents the space; the area of the base Ft the momentum; and the cubic contents $Fvt = FS = Pt$, represents the work, provided that the force F and velocity v, are constant in the time t. But when F and v are either, or both, variable, they will generate and be represented by various other figures. In the case of a constant force F, acting on a mass free to move, the velocity will be variable with a uniform acceleratrix, then the work done will be represented by a wedge.

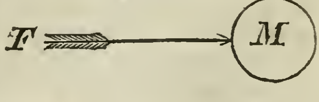


Fig 2

Let a constant force F, fig. 2, act on a mass or body M, in the direction of the arrow, F and M being expressed by the same unit of weight, say pounds, and no other force acting on M; then we know from the law of gravity that the acceleratrix of the force F will be

$$G = \frac{gF}{M}.$$

Let the force F act on M for any length of time T, then we know from the law of gravity that the final velocity attained will be,

$$V = GT.$$

Let v denote the velocity at any time t, both less than V and T, then the power in operation will be,

$$P = Fv,$$

and the differential work will be,

$$dW = Fv\,dt,$$

but $v = Gt$ and

$$dW = FGt\,dt,$$

when

$$W = \int_{t=0}^{t=T} FGt\,dt.$$

$$W = \overset{1}{\frac{GFT^2}{2}} = \overset{2}{\frac{FVT}{2}} = \overset{3}{\frac{FV^2}{2G}},$$

which are the three forms of work accomplished by the constant force F, acting on the body M in the time T.

We know that $F = \frac{GM}{g}$, which inserted in the above members, will give,

$$W = \overset{4}{\frac{G^2MT^2}{2g}} = \overset{5}{\frac{GMVT}{2g}} = \overset{6}{\frac{MV^2}{2g}}.$$

These are the three forms of work concentrated in the moving body M.

Comparing the 2d and 6th members we have,

$$\overset{2}{\frac{FVT}{2}} = \overset{6}{\frac{MV^2}{2g}}; \text{ or } \overset{7}{FVT} = \overset{8}{\frac{MV^2}{g}} = 2W, \text{ which was to be proved.}$$

When M denotes the mass of the body, we have $FVT = MV^2$

This is the equation which Prof. Wood in his criticism proved to be "*an absurdity under every hypothesis.*" I cannot omit to state that his reasoning must be very elastic.

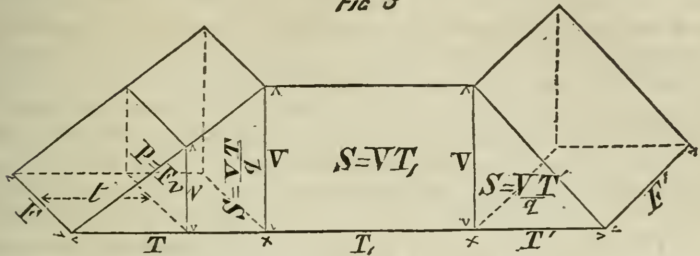
The member MV^2 is the mysterious quantity *Vis-viva*, which I shall endeavor to bring bodily to sight.

The velocity V in the preceding formulas, does not signify the *mean* velocity of the force F, but the *final* velocity imparted by the force F to the body M, in the time T; or the uniform velocity of the body M after the force F has ceased to act upon it. This *final* velocity at the time T, is just twice the *mean* velocity of F in the time T, when F and the acceleration G are constant as here supposed.

An illustration may form a clearer conception of the nature of the preceding formulas.

Let the line F, fig. 3, represent the magnitude of a constant force acting on a body free to move in the direction t; the line T to represent time; any ordinate v to represent the velocity of the force F at any corresponding time t, until F ceases to act, when the *final* velocity V will be constant. The hypothenuse for the catheters T and V, will become a straight line when the acceleration of F is constant. Then the area

Fig 3



of the cross section $P = Fv$ represents the power in operation at the time t; the area of the triangular side represents the space $S = \frac{vt}{2}$, passed through by the force F; the work done in the time t, is represented by the cubic contents of the wedge $\frac{Fvt}{2}$, or for the whole time T,

$$W = \frac{FVT}{2}.$$

When the force F ceases to act at the end of the time T, the body will continue with a uniform velocity V, and pass through the space $S = VT_{\prime}$, with its concentrated work $W = \frac{FVT}{2}$, until we will suppose some force F' is applied to stop it.

The linear space S which the body passes through in the time $T_{\prime}$, is on the figure represented by the rectangular area $VT_{\prime}$, constituting the elements of space.

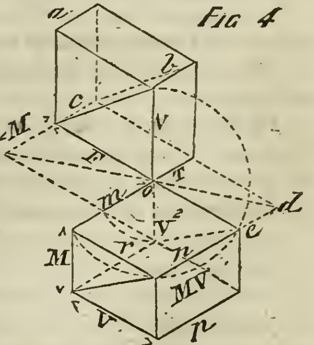
The body will come to rest when the work of the opposing force F' is equal to the work accomplished by the force F, or when $\frac{1}{2}F'V'T' = \frac{1}{2}FVT$. Let the common factor $\frac{1}{2}V$ be eliminated, and the momentums $F'T' = FT$, when the body comes to rest.

It has before been proved that,

$$2W = FVT = MV^2,$$

and the momentum $FT = MV$.

Fig 4



Now let the parallelopipedon a, b, T, c, fig. 4, represent FVT, which as before shown, is double the work, when $V = final$ velocity; then the base will represent the momentum FT. Continue the line F from o to e, make $oe = V$; complete the rectangle T, d, e, draw the diagonal d, o, continued to M; c and M being in a straight line; then M represents the magnitude of a mass in which is accumulated the work $\frac{1}{2}FVT$. Complete the square V^2, and draw on it the figures m, e, p, V, M; which then represent the so-called *Vis-viva* MV^2, in a moving mass, of which only one-half, or the wedge m, n, r, is realized as substance, while the other half, or the wedge n, r, p, remains in mystery.

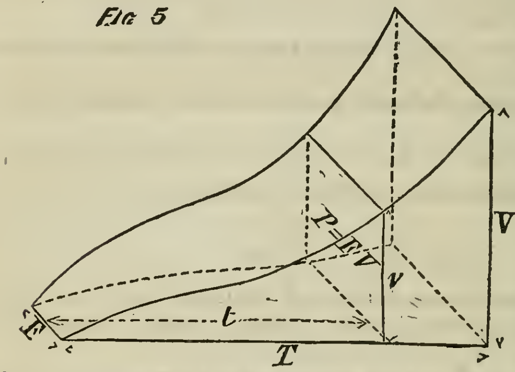
Vis-viva is the most unfortunate term in dynamics, inasmuch as it does not express what it means, neither in substance nor in quantity. There is no more *vis-viva* in a moving mass, than in one at rest. It requires Fvt and nothing else to set a mass in motion; it requires Fvt and nothing else to bring a moving body to rest; and it is Fvt and nothing else that can change the motion of a body.

The sooner the term *vis-viva* is rejected in its present acceptation, the sooner will the science of dynamics be cleared up. Whatever name may be selected for the work concentrated in a moving mass, it ought to express the fundamental elements F, V, and T. I would propose to call it energy, but even if the term *vis-viva* is maintained, it ought to mean the true work $\frac{1}{2}MV^2$, and not MV^2.

A parallelopipedon constructed on the mean velocity will represent the true work Fvt.

When the force F is variable, as represented by fig. 5, the hypothenuse of the catheters F and V, will be a curved line, the form of which depends on the nature of variation of F, but the work will still be

FIG 5



$$W = \int F\,G\,t\,dt, \text{ as before.}$$

Momentum, $MV = \int F\,dt.$ Velocity, $V = \frac{1}{M}\int F\,dt.$

Space, $S = \int dv \int F\,dt.$ Power, $P = \frac{F}{M}\int F\,dt.$

Work, $W = \int P\,dt = \Sigma F\,v\,t = \frac{MV^2}{2g},$

which will represent the work under all circumstances.

The form of the figure of work depends on the nature of variation of F and v.

In the case of a body moving through a fluid, as a vessel through the water, a bomb through the air, where the resistance is as the square of the velocity, the figure of work will be a pyramid.

Comparing the members 1 and 5, page 184, we have,

$$\overset{1}{\frac{GFT^2}{2}} = \overset{5}{\frac{GMVT}{2g}}, \text{ or the}$$

Momentum,

$$\overset{9}{FT} = \overset{10}{\frac{MV}{g}},$$

For circular motion we have the velocity,

$$11 \qquad V = \frac{2\pi R n}{60}$$

which inserted in the member 10, will be

$$12 \qquad FT = \frac{M 2\pi R n}{60 g},$$

in which R = radius of gyration of the rotating body, and n = number of revolutions per minute.

A force multiplied by the lever it acts upon, is called *static momentum*; which is analogous to the force of inertia multiplied by the radius of gyration MR, which seem to have a claim to be called *moment* of *inertia.*

The square of the member 11, inserted in the member 6, will represent the work concentrated in a revolving mass, or

$$W = \frac{M 4\pi^2 R^2 n^2}{3600 \times 2g} = \frac{MR^2 n^2}{5866 \cdot 8},$$

of which the part MR^2 has been denominated moment of inertia.

I was in error in my statement that "Moseley called moment of inertia, Work." I ought to have said that the substance of the so-called moment of inertia MR^2, is work when n is constant.

Prof. Wood refers to his two articles on *Vis-viva*, published in the November number, 1862, and in the February number, 1864, of this Journal. I beg leave to state that the confusion existing in those articles was one of the many reasons why I undertook to write on the subject, which was stated in the October meeting of the Franklin Institute; for in both those articles, as well as in the general criticism on mine, *force*, *power* and *work*, are confounded with each other.

The article in the November number, 1862, page 351, commences in this way: "*When we consider that eminent scholars have taken different views upon the measure of the force in a moving body, it is not strange that students, while yet in the elements of mechanical science, should be at a loss to know whether the force varies as the velocity or as the square of the velocity.*" Here the Professor confounds force with work and momentum. The force of inertia in a moving mass is equal to whatever external force is applied to change its motion. The different views taken by eminent scholars and students are, whether *power* or *work*, is as the velocity or as the square of the velocity. The Professor continues, "*They do not see why the momentum does not express the force as well as the Vis-viva; or they fail to distinguish between the two forces.*" Force is neither momentum nor *Vis-viva.* Force is, as far as we yet know, a simple element; whilst momentum is a compound of two elements, and *vis-viva* a compound of three elements. The momentum in question is derived from the analogy

$$F : M = V : T, \text{ or } FT = MV.$$

The momentum FT is equal to the momentum MV. It is the momentum MV which the Professor calls one kind of force as different from MV^2, another kind of force! The momentum MV is substantially the same as the product obtained by multiplying six horses by four bushels of barley; it must be multiplied or divided by some element before it can be recognised as a physical quantity; if we multiply MV by V, the product will be work; multiply MV by $\frac{G}{g}$, the product will be power; divide it by T and it will be force; divide it by F and it becomes time. If 6 horses can eat 3 bushels of barley, how many horses can eat 4 bushels? Here we multiply 6 horses by 4 bushels of barley, which will be only a momentum to be divided by 3 bushels of barley, when the result will be eight horses. On the same page, 351, Prof. Wood says, "*The force which is stored in a moving body, is a force of inertia; hence it is equivalent to the force which would cause the body to move from a state of rest to a velocity* V, *when free to move without any resistance.*"

It is most difficult in this case to distinguish if the Professor means force or work. The force of inertia in a body free to move, is equal to any external force applied to change its motion; but the force which has set the body in motion has no necessary relation with the force which may bring it to rest, except with consideration of time, as in case of gravity acting on a pendulum; but the work expended in setting a body in motion, is equal to the work required to bring it to rest.

On the next page, 352, Prof. Wood gives an example of momentum by multiplying the weight of a moving mass 200 lbs by its velocity 2 feet, and calls the product 400 lbs feet, but does not state what kind of foot-pounds. Can this momentum lift 400 lbs one foot high in a unit of time or independently of time? Next the Professor gives an example of *Vis-viva*, by multiplying the same mass 200 lbs by the square of its velocity or $200 \times 2^2 = 800$, but does not state what kind of substance this 800 is. From the commencement of his article we are led to suppose it to be force. The fact is that the *Vis-viva* 800 is in substance foot-pounds of work; while the momentum 400 multiplied by $\frac{G}{g}$ will be in substance foot-pounds of power. The Professor, however, admits that his example may appear paradoxical. The difference between foot-pounds of power and foot-pounds of work, is the same as the difference between square feet and cubic feet. Prof. Wood thinks that "*the reason why much obscurity has hung over the subject, is principally on account of brevity of treatment by most authors.*" I do not believe that such is the case, but is owing rather to a want of clear conception on the subject, which all our treatises testify by their unnecessary complication and confusion. Professor W. gives me credit for the definition of *power*, to be "*force* multiplied by *velocity*." I learned that at the Royal Technological Institute in Stockholm, when I was a boy, and it is so used by all practical steam engineers throughout the world, for calculating the power of steam engines. The force on the steam piston multiplied by its velocity, is the power of the engine.

The definitions of *force*, *power* and *work*, are intended only to hold good in the science of dynamics. I will not undertake to define those terms as they are used in popular language. The only new term I proposed in my article, was *Workmandays*.

In the first formula for work under action of gravity, page 331 last volume, the number 2 is left out in the denominator. It should read,

$$W=\frac{M\,V^2}{2g\,550\times 3600}$$

On the Chemical History and Application of Gun-Cotton. By Prof. ABEL, F.R.S., Chemist to the War Department.

From the London Chemical News, No. 236.

Continued from page 138.

A rapid current of air will also effect the transformation of the combustion of gun cotton from the ordinary to the slow form if the yarn be enclosed in a moderately wide glass tube, with one end protruding from the tube so that it may be inflamed in the ordinary manner, but, unless the current be very rapid, an explosive mixture of air and the inflammable gases generated from the gun cotton may be produced in the tube, and become ignited, in which case the gun cotton will flash into flame instantaneously, and the tube will be shattered by the explosion. If, however, a long thin piece of gun cotton-yarn be passed through a small, narrow, glass tube, one or two inches long into which it fits so loosely that it may be drawn through very easily, the change in the form of combustion is effected with certainty and without the aid of a current of air. When the gun cotton thus arranged and placed upon a flat surface is inflamed at one extremity, it burns as usual until it reaches the one opening of the tube; the slow form of combustion then takes place within the tube, and the gun cotton will continue to burn in the slow manner, emitting only the small tongue of flame after the combustion has reached the portion of yarn on the other side of the tube, which will be entirely burned in this peculiar manner. In fact, to change the ordinary into the slow form of combustion of the gun cotton-yarn *in open air*, it is only necessary to pass a piece of the material through a perforation in a diaphragm of wood, card-board, or paper, and to allow it to rest upon a flat surface on both sides of the diaphragm. The gun cotton will burn as usual on one side of the screen, until its combustion reaches the perforation, when the large bright flame will vanish and the gun cotton upon the other side of the screen will burn in the slow manner to the end.

The two last experiments show that, if the combustible mixture of gases evolved by the action of heat upon gun cotton when it is inflamed in open air are prevented, even for the briefest space of time, from completely enveloping the burning extremity of the yarn or twist; or, in other words, if they are forced for an instant to escape only in a direct line with the burning surface of gun cotton from which they are emitted, those particles of the latter which are in immediate proximity to the burning portion cannot be raised to the temperature necessary for their rapid and more complete combustion, and hence the gases themselves are, in turn, not supplied with sufficient heat for their ignition. Now, as the gases which escape unburned convey away a very large portion of the heat developed by the metamorphosis of the gun cotton, it is impossible for the latter to continue to burn otherwise than in the slow and imperfect manner. If, however, a flame or highly heated body be held in the path of the gases as they escape, they will at once be ignited, and the yarn will burst into the ordinary form of combustion. The correctness of this explanation may readily be demonstrated by two or three simple experiments. Thus, if a piece of loose or open gun cotton-yarn is employed in place of the compact material which furnishes the results just described, it is very difficult, or even impossible, to cause the rapid combustion to pass over into the slow form, because the escaping gases cannot be diverted all into one direction, and cannot, therefore, be prevented from transmitting the heat necessary for perfect combustion from particle to particle of the material. Again, if a piece of the compactly twisted gun cotton-yarn, placed upon a flat surface, is inflamed in the usual manner, and a jet of air is then directed in a line with the gun cotton so as to meet the flame, the latter will appear to be blown out, though the cotton still burns; in fact, the burning gases are prevented for an instant from completely enveloping the extremity of the gun cotton, and hence the combustion at once passes from the quick to the slow form. Conversely, if, when the yarn has been made to burn in this slow manner, a very gentle current of air be directed against the burning portion so as to force back upon the latter the gases which are escaping, thus impeding the raqid abstraction of heat, it will very speedily burst into the ordinary form of combustion, because, under these circumstances, the gases are almost immediately raised to the temperature necessary for their combustion. In the same way, if a piece of the yarn, placed upon a board, be made to burn in the slow manner, and one end of the board be gradually raised so that the burning extremity of the gun cotton is the lowest, the latter will burst into flame as soon as the board has been raised to a position nearly vertical, so that the escaping gases flow back upon the burning surface.

The slow or imperfect form of combustion may be at once induced in the compact gun cotton-yarn, in open air, by applying to any part of the gun cotton a source of heat not sufficiently great to inflame the gases generated. A wire or metal rod, heated to any temperature between 135° C. to just below visible redness, or the spark of a thin piece of smouldering string, will invariably produce the result described. Of course, this effect, like most of the phenomena described, is to a considerable extent dependent upon the mechanical condition of the gun cotton, upon the relation between the *quantity* as well as the *degree* of heat applied, and the amount of surface of the gun cotton, and upon other conditions. While a small spark, or a thin platinum wire heated to full redness, only induces slow combustion in the compact gun cotton-yarn, a thick rod of iron heated only to dull redness will invariably inflame it in the ordinary manner. A piece of open yarn cannot be ignited so as to burn in the slow manner; on the other hand, the more compactly the gun cotton is twisted, the more superficial is the slow form of combustion induced in it; indeed, the gun cotton may be rendered so compact that it will simply smoulder in open air, if ignited as described, leaving a considerable carbonaceous residue; and the heat resulting from this most imperfect combustion will sometimes be abstracted, by the escaping gases, more rapidly than it is developed, so that the gun cotton will then actually cease to burn, even in open air, after a short time.

The remarkable facility with which the effect of heat upon gun cotton may be modified, so as even to produce results totally opposite in their characters, as exemplified by some of the experiments which have been described, renders it easily conceivable that this material may be made to produce the most varied mechanical effects, when applied to practical purposes; that it may, indeed, be so applied as, on the one hand, to develope a force, very gradual in its action, which may be directed and controlled at least as readily as that obtained by the explosion of gunpowder; while, on the other hand, it may be made to exert a violence of action and a destructive effect far surpassing those of which gunpowder is susceptible. The results arrived at in Austria, which show that gun cotton can be made to produce effects from three to eight times greater than those of gunpowder, cease to be surprising after a study of the chemical and physical characteristics of this interesting explosive agent.

The products obtained by the explosion of gun cotton and its decomposition under various conditions have as yet been very imperfectly studied, but there is little doubt that they vary in their nature almost as greatly as the phenomena which attend the exposure of the material to heat under different circumstances. It is well known that when gun cotton is inflamed in the open air there is produced—in addition to water, carbonic oxide, carbonic acid, and nitrogen—a considerable proportion of binoxide of nitrogen, so that the gaseous mixture assumes a red brown tinge, and becomes very acid, when it mixes with air. The products of the varieties of imperfect combustion which gun cotton has been described as susceptible of undergoing are undoubtedly much more complex in their character than those just referred to. They include at times a proportion of some substances not yet examined, which make their appearance as a white vapor or smoke. Cyanogen can readily be detected in all the products of imperfect combustion. The proportion of binoxide of nitrogen is generally so large that the gaseous product becomes very highly colored when mixed with air. Peroxide of nitrogen has also been observed in some instances. Lastly, there is little doubt that the products occasionally include a proportion of oxidizing gases.

The products which have just been alluded to are the results of the decomposition of gun cotton either at ordinary or diminished atmospheric pressures. When the explosion of the material is effected in a confined space, in such a manner that the main decomposition takes place under pressure, the metamorphosis which the material undergoes is of more simple and complete character.

It has been found by Karolyi that when gun cotton is exploded by voltaic agency, in a shell which is burst by the explosion, and which is enclosed within an exhausted chamber so that the products of decomposition are collected without danger, the results obtained, under these conditions, are comparatively simple; the analysis of the contents of the chamber after the explosion showed that they consisted of—Carbonic acid, 20·82 per cent.; carbonic oxide, 28·95; nitrogen, 12·67; hydrogen, 3·16; marsh gas, 7·24; water, 25·34; and carbon, 1·82. The decomposition of gun cotton under these conditions, which are similar to those of its explosion when employed as a destructive agent, appears therefore, not to be attended by the production of any oxide of nitrogen. The lecturer found in some preliminary experiments made under the same conditions as those of Karolyi, that only a minute proportion of binoxide of nitrogen was produced. These results, when compared with those obtained by the ignition of gun cotton in open air and rarefied atmospheres, show that, just as the decomposition of this material is of a more complicated and intermediate character, in proportion as its combustion is rendered imperfect by diminution of pressure or other circumstances, so, conversely, the change which it undergoes will be the more simple, and its conversion into gaseous products the more complete, the greater the pressure, beyond normal limits, under which it is exploded—that is to say, the greater the resistance offered to the generated gases upon the first ignition of a charge of gun cotton (and, consequently, the higher the temperature at which the decomposition of the confined gun cotton is effected). It is, therefore, readily intelligible that the notions hitherto generally entertained with regard to the very noxious character of the products of explosion of gunpowder and their powerfully corrosive action upon metals, based as these notions have been upon the effects observed on exploding gun cotton in open air, have been proved to be erroneous by the results of the actual application of gun cotton to artillery and other purposes. The foregoing considerations contribute, moreover, to the ready explanation of the fact established by the experiments in Austria, that the destructive effect of gun cotton is greatly increased, within certain limits, by increasing the resistance which the products of explosion have to overcome before they can escape into the air.

The conditions (of temperature, pressure, &c.) which influence the nature of the decomposition of gun cotton, exert, unquestionably, a similar influence upon the nature of the explosion of gunpowder, and upon the mechanical effects which its products are capable of exerting. Observations made by the lecturer in experiments upon the ignition of gunpowder in rarefied atmospheres point to the existence of products of comparatively complicated character among those found by the gradual decomposition of that material, under the conditions described. The earlier investigators (Guy Lussac, Chevreul, &c.) of the products of explosion of gunpowder represent these as being of very simple character, and in harmony with the theory that gunpowder is converted essentially by its explosion into carbonic acid (or a mixture of that gas and carbonic oxide), nitrogen, and sulphide of potassium. But more recent experimenters, Bunsen and Schischkoff, who have made a very elaborate examination of the products which they obtained by the explosion of gunpowder, represent the change to be one of a very complicated character; fix the percentage of solid substances found at a much higher figure than that hitherto accepted; and show that the sulphide of potassium, which has hitherto been considered as the principal of these products, was only produced in very small proportion in their experiments. The conditions under which these chemists exploded the gunpowder did not, however, correspond in their character at all to those under which gunpowder is exploded in actual practice, and would, therefore, be very likely to furnish results greatly at variance with those produced when a charge of powder is fired in a gun, a shell, or a mine. That sulphide of potassium is abundantly produced upon the discharge of a firearm appears beyond doubt; it may be readily detected in the solid matter which remains in the barrel near the breech; it may be found deposited in considerable quantity near the muzzle of the arm; and there appears strong reason for believing that the flash of flame observed at the mouth of a firearm, upon its discharge, is due in part to the ignition, as it comes into contact with the air, of sulphide of potassium, which has been vaporized by the heat of the explosion, and is thus mixed with the escaping gases.

In comparing the effects of gun cotton, as an explosive agent, with those of gunpowder, and in basing theories with regard to the difference in the mechanical effects exerted by the two, upon the analytical results of the products of their explosion which have been obtained up to the present time, it is necessary to proceed with great caution; for exceptional results cannot form any sound basis for correct theories or tenable arguments. It can only lead to incorrect conclusions, which may considerably retard the thorough investigation of a most important subject, if the facts be ignored or lost sight of—that, first, the conditions which practically influence the nature of the products of the explosion of gun cotton have a similar influence upon the changes which gunpowder may be made to undergo; and that, secondly, the effect of heat upon the water produced by the decomposition of gun cotton, which forms so important an element in the action of this explosive, has most probably its parallel, to no unimportant extent, in the vaporizing effect of heat upon the solids (especially upon sulphide of potassium) produced in the explosion of gunpowder. These are matters which demand their full share of consideration and investigation before it can be admitted that a sufficient explanation of the remarkable differences between the effects of gunpowder and gun cotton exists in the assumption that certain products of decomposition of the former must be regarded entirely as waste matter in the material, simply because they are solid *at ordinary temperatures.* The fact that gun cotton is *entirely* converted into gases and vapor *at the moment of ex-*

plosion constitutes unquestionably one of the great advantages which that substance possesses over gunpowder; but it is premature, at present, to assume, in comparing the action of the two substances, that only 32 per cent. (or even 60 per cent.) of gunpowder exist as gas or vapor *at the moment of its explosion.*

It is to be expected that the investigations which are now being actively pursued upon the true chemical effects produced in the explosion both of gun cotton and gunpowder, under conditions similar to those which attend their employment in practice, will aid materially in furnishing the correct data so essential for a thorough and impartial comparison of the nature and merits of these two explosive agents.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 245.

(Continued from vol. xlviii., page 408.)

7. *Discovery of Boyle's Law.*—About a year after the publication of Boyle's "Physico-Mechanical Experiments," Francis Linus published a treatise* in which he sought to prove the impossibility of the production of a vacuum, and the consequent fallacy of the results obtained by Boyle. The objections brought forward by Linus are, if possible, more absurd than those of Hobbes; they were very ably answered by Boyle,† and utterly unreasonable as was the theory on which they were based, we cannot but feel glad that it was propounded, inasmuch as in making experiments for its refutation, Boyle discovered the celebrated law of the compression of gases.

Linus admitted that the air possesses both weight and elasticity, but he denied that it is competent, in virtue of those properties, to produce the effects attributed to it by the vacuists.

One of the chief arguments adduced by Linus, against the explanation given by the vacuists of the Torricellian experiment is the following:—If we take a tube less than 29½ inches long, say 20 inches, fill it with mercury, and then invert it in a vessel of mercury, the upper orifice of the tube being closed by the finger, the latter is found to be strongly pressed down; now, he reasons if the air can support 29½ inches of mercury, and there are but 20 inches in the tube, the finger ought to be pressed upwards instead of downwards. To this Boyle answers very truly, that the finger has greater pressure on its upper surface than on its lower, because it has to bear the whole weight of the atmosphere on its upper surface, whereas below it has to bear the weight of the atmosphere — the weight of the column of mercury in the tube; hence, if there are 20 inches of mercury in the tube, the lower surface of the finger will be pressed upon by only one-third of the weight which presses upon its upper surface.

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* "De Corporum Inseparabilitate, 1661."

† See "A Defence of the Doctrine touching the weight and spring of the air, proposed by Mr. Boyle in his new Physico-mechanical experiments, against the objection of Franciscus Linus." By the Author of those experiments. London: 1662.

Again, argues Linus, if a tube 20 inches long is nearly filled with mercury, the upper orifice closed by the finger, and the lower opened beneath the surface of mercury, the mercury in the tube will descend somewhat, and the finger will be pressed strongly against the tube, if the air, then, cannot support 20 inches of mercury, how can it support $29\frac{1}{2}$ inches? And if it be argued that the spring of the included air pushes down the mercury, it follows that the finger ought to be pushed upwards; but, answers Boyle, the upper part of the finger has to bear the whole weight of the atmosphere, whereas the air in the tube beneath the finger has the weight of the column of mercury to help it to overcome the weight of the atmosphere.

In order to account for the suspension of the mercury in the Torricellian experiment, Linus proposed his "Funicular hypothesis," which affirmed that the mercury remains suspended in the tube by a "funiculus" or cord of very thin matter, which is forcibly distended by the weight of the mercury, and perpetually endeavors to contract; when the mercury column has distended it to the extent to which such a weight is competent, the column rests suspended in the tube by the funiculus. Not only the Torricellian experiment, but all the effects affirmed by the vacuists to be due to the weight and elasticity of the air were attributed by Linus to the action of his funiculus.

Boyle speaks of the theory as being "partly precarious, partly unintelligible, and partly insufficient, and besides needless;" it is curious, moreover, he remarks, that the funiculus should not only support a column of such a heavy liquid as mercury, but should also be able to draw in the sides of a glass vessel with sufficient force to break it; it is also remarkable that a pendulum should vibrate so readily in an exhausted receiver, if it has to cut through a number of stretched cords.

Pascal's Puy de Dôme* experiment proved decisively the fallacy of all the theories of the Plenists; Linus was well aware of this, and he chose to doubt the accuracy of the experiment, because having tried it on the summit of a hill of but small elevation, it did not appear to succeed. Boyle replies that inasmuch as the Puy de Dôme experiment had been repeated five separate times, and had also been made in England with similar results, there can be no doubt of its accuracy. Mr. Richard Townly, a friend of Boyle's modified the experiment by allowing a small quantity of air to remain in the tube above the mercury, and he found this enclosed air occupied a larger volume on the summit of a mountain than at its base.

In order to prove that the experiment obtains with small elevations, Boyle constructed a modified air thermometer, which would indicate very slight changes in the pressure of the air. This instrument consisted of a capacious glass bottle, into the neck of which a glass tube open at both ends was cemented; the tube reached nearly to the bottom of the vessel, and dipped beneath the surface of a small quantity of water placed therein, thus the air within the vessel had no communication with that outside; increase of pressure of the air would obviously cause the water to sink within the tube; whereas diminution of pressure would cause the air within the instrument to expand, and consequently to raise the water in the tube above the level of that in the vessel; it is needless to remark that such an instrument would only show difference of pressure in the air when the temperature was constant. The exact height at which the water stood on the ground was observed. Boyle then drew up the instrument by a rope to the leads of Westminster Abbey, a height of seventy-five feet from the ground; the water was found to have risen one inch in the tube, the temperature remaining constant.

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* For an account of this experiment see the third of these papers, *Chemical News*, vol. viii, p. 247.—Journal Frank. Ins. vol. xlviii, p. 171.

We come now to the discovery of the important law which affirms that *the volume of a gas varies inversely as the pressure to which the gas is submitted*, and inasmuch as there is some dispute as to whether Boyle or the French philosopher Mariotte was the first to discover the law, we will consider the subject somewhat in detail.

In France and Germany the law is almost universally called "the law of Mariotte," in England generally "the law of Boyle and Mariotte," sometimes "the law of Mariotte," seldom "the law of Boyle." I shall endeavor to prove that it is rightly the law of Boyle.

Roberval* enclosed a partially inflated carp's bladder in the Torricellian vacuum, and observed that it became fully inflated. Boyle made the same experiment with a lamb's bladder in the vacuum produced by his air-pump; on exhaustion, the bladder became fully inflated, and on the re-admission of air contracted to its former dimensions; he next inclosed air in a tube and measured its expansion on the removal of pressure; it was found to expand more and more with every stroke of the pump, until eventually it occupied 152 times its original bulk, to which latter it returned on the re-admission of air. Here, then, was the important fact that the greater the amount of pressure removed from air the more does it expand.

In order to see if the pressure of the air is the sole cause of the suspension of the mercury in the Torricellian experiment, Boyle (in the 17th of the Physico-mechanical experiments †) filled a tube three feet long with mercury and inverted it in a vessel of mercury, which latter he placed in the air-pump receiver, the tube being passed air-tight through its cover; on exhausting, the mercury fell lower and lower with every stroke of the pump, till it was almost on a level with the mercury in the vessel in which the lower end of the tube was placed; on admitting air into the receiver, the mercury rose above twenty-nine inches, on letting out the air it sank again to that height. It was thus indisputably proved that the height of the mercury is greater or less according as the density of the air pressing upon it is greater or less.

As the capacity of the receiver and of the air-pump cylinder could be readily determined, and thus the fall of the mercury in the tube due to the removal of a known amount of air, Boyle hoped to be "enabled to give a near guess at the proportion of force betwixt the pressure of the air (according to its various states, as to density and rarefaction) and the gravity of quicksilver," but on account of several difficulties which he mentions, and of the little leisure at his disposal, he says he shall content himself with having suggested the experiment.

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* This experiment is first mentioned in a work which was published by the Academia del Cimento, and which contains an account of the experiments made by its members. Of this important scientific society we shall have to speak hereafter.

† This and the previous experiment have been before mentioned in the fourth and fifth of these papers. They are introduced here because they bear upon the discovery of Boyle's law.

We see, therefore, that prior to 1660 Boyle suggested a method for determining the relation of the density of air to the weight which it supports. After making the experiments given above, the discovery of Boyle's law was inevitable; no thinking man could make those experiments without inquiring whether the removal of a definite amount of pressure caused a definite expansion of the released air.

Let us now pass on to the actual discovery of the law.

The fifth chapter of the second part of Boyle's "Defence against Linus," is entitled "Two new experiments touching the measure of the force of the spring of air compressed and dilated."

Linus, as before mentioned, had throughout his treatise affirmed that the elasticity of the air is incompetent to produce the effects attributed to it by the vacuists; the experiments detailed in this chapter were made by Boyle in order to prove that the spring of the air is able to effect not only as much but far more than the vacuists attribute to it.

To prove this Boyle procured a long glass tube, and bent it in the form of a syphon with parallel limbs, each of which was divided into inches and eighths; one limb was considerable shorter than the other, and its orifice was hermetically sealed,* (in fact, the instrument was exactly similar to that which we use in the present day for illustrating Boyle's law.) Mercury was poured into the instrument until it stood level in each limb, at the commencement of the scale, mercury was then poured into the longer limb until the air in the shorter was reduced to half its original bulk, "when," he writes, "we cast our eyes upon the longer leg of the glass on which we likewise pasted a list of paper carefully divided into inches and parts, and we observed, not without delight and satisfaction, that the quicksilver in that longer part of the tube was twenty-nine inches higher than the other." . . . "We were hindered," he continues, "from prosecuting the tryal at that time by the casual breaking of the tube. But because an accurate experiment of this nature would be of great importance to the doctrine of the spring of the air, *and has not yet been made* (*that I know*) *by any man*, . . . we at last procured a tube of the figure exprest in the scheme." This tube was exactly similar in form to the other, but larger in its dimensions; from experiments made with it Boyle deduced the following table which he calls

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*Boyle had previously (in the 36th of the Physico-mechanical experiments) made use of a similarly shaped tube open at both ends for determining the relative weights of water and mercury. Mercury was poured into the tube till it stood level in each limb at the commencement of the scale: water was then poured into the longer limb and it was found that $30\frac{45}{54}$ inches of water balanced $2\frac{13}{45}$ inches of mercury, making the relative weights of mercury and water as 1 to $13\frac{92}{121}$.

"A Table of the Condensation of the Air."

A Space occupied by the air in the shorter limb of the instrument in inches.	*B* Height of the column of mercury in the longer limb, the weight of which column caused the change of volume shown in *A*.	*C* Pressure sustained by the air in the shorter limb expressed by the height of the column of mercury in the longer limb $+29\frac{1}{8}$ inches, the height of the column of mercury supported by the atmosphere.	*D* Theoretical pressure sustained by the air in the shorter limb, if we suppose "the pressures and expansions to be in reciprocal proportions.
12	00	$29\frac{2}{16}$	$29\frac{2}{16}$
$11\frac{1}{2}$	$01\frac{7}{16}$	$30\frac{9}{16}$	$30\frac{6}{15}$
11	$02\frac{13}{16}$	$31\frac{15}{16}$	$31\frac{12}{16}$
$10\frac{1}{2}$	$04\frac{6}{16}$	$33\frac{8}{16}$	$33\frac{1}{7}$
10	$06\frac{3}{16}$	$35\frac{5}{16}$	35
$9\frac{1}{2}$	$07\frac{14}{16}$	37	$36\frac{15}{19}$
9	$10\frac{2}{16}$	$39\frac{4}{16}$	$38\frac{7}{8}$
$8\frac{1}{2}$	$12\frac{8}{16}$	$41\frac{10}{16}$	$41\frac{2}{17}$
8	$15\frac{1}{16}$	$44\frac{3}{16}$	$43\frac{11}{16}$
$7\frac{1}{2}$	$17\frac{15}{16}$	$47\frac{1}{16}$	$46\frac{3}{5}$
7	$21\frac{3}{16}$	$50\frac{5}{16}$	50
$6\frac{1}{2}$	$25\frac{3}{16}$	$54\frac{5}{16}$	$53\frac{10}{13}$
6	$29\frac{11}{16}$	$58\frac{13}{16}$	$58\frac{2}{8}$
$5\frac{3}{4}$	$32\frac{3}{16}$	$61\frac{5}{16}$	$60\frac{18}{23}$
$5\frac{1}{2}$	$34\frac{15}{16}$	$64\frac{1}{16}$	$63\frac{6}{11}$
$5\frac{1}{4}$	$37\frac{15}{16}$	$67\frac{1}{16}$	$66\frac{4}{7}$
5	$41\frac{9}{16}$	$70\frac{11}{16}$	70
$4\frac{3}{4}$	45	$74\frac{2}{16}$	$73\frac{11}{19}$
$4\frac{1}{2}$	$48\frac{12}{16}$	$77\frac{14}{16}$	$77\frac{2}{3}$
$4\frac{1}{4}$	$53\frac{11}{16}$	$82\frac{12}{16}$	$82\frac{4}{17}$
4	$58\frac{2}{16}$	$87\frac{14}{16}$	$87\frac{3}{8}$
$3\frac{3}{4}$	$63\frac{15}{16}$	$93\frac{1}{16}$	$93\frac{1}{8}$
$3\frac{1}{2}$	$71\frac{5}{16}$	$100\frac{7}{16}$	$99\frac{6}{7}$
$3\frac{1}{4}$	$78\frac{11}{16}$	$107\frac{13}{16}$	$107\frac{7}{13}$
3	$88\frac{7}{16}$	$117\frac{9}{16}$	$116\frac{4}{8}$

Boyle next made some experiments on the expansion of air under diminished pressure. He was informed, however, by the afore-mentioned Mr. Townley, that he (Mr. Townley), since reading the "Physico-Mechanical Experiments," had endeavored—acting, I suppose, on the suggestion given by Boyle in the seventeenth experiment mentioned above—to determine the amount of expansion of a certain quantity of air on the removal of known amounts of pressure. Townley had commenced a paper on the subject, which he showed to Boyle, but it was apparently never published.* Boyle does not mention whether he employed the same method as that adopted by Townley.

Boyle's method was the following :—A long tube, one end of which was open and the other hermetically sealed, was divided into inches and eighths; it was filled with mercury and placed in a vessel of mercury of the same depth as itself. One inch of air was then passed into the upper part of the tube, the mercury within and without being brought to the same level. The tube was now raised till the air within it had expanded to double its volume, and the pressure acting upon it determined by subtracting the height of the column of mercury below the air from 29¾ inches, which at the time of making the experiment was the height of the column of mercury supported by the atmosphere. The arrangement of the apparatus was exactly the same as that figured in our present works on physics. Boyle gives a table of the results which he obtained, which he calls "A Table of the Rarefaction of the Air."

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* There are several papers by Townley in the early numbers of the *Philosophical Transactions*, but not one of them relates to the subject in question; neither do I find mention of any paper by Townley on the subject in Watt's "Bibliotheca Britannica."

Let us now consider the claims of Mariotte.

*Fourteen years** after Boyle published the above experiments, Mariotte's "Essai sur la Nature de l'Air," first made its appearance. In this essay† Mariotte informs the reader that the first great property of the air is that it possesses weight, the second that it is capable of condensation and expansion; he then passes at once to the question whether the air is condensed in exact proportion to the weight which acts upon it. In order to ascertain this, Mariotte, together with a M. Hubin, procured a glass tube 40 inches long, sealed one end of it hermetically, and poured in mercury until it stood at 27½ inches from the end of the tube, the open end was then closed by the finger, the tube inverted, and opened beneath the surface of mercury; the mercury in the tube fell till it rested 14 inches above that in the vessel, and the air occupied 25 inches; 24 inches of mercury were next placed in the tube, on inverting the mercury fell to 7 inches, and the air occupied 32 inches; by these and other experiments, made with different quantities of mercury in the same tube, similar results were obtained. We may, therefore, writes Mariotte, take it "pour une régle certaine, ou loi de la nature, que l'air se condense à proportion des poids dont il est chargé."

The truth of this law he continues, may be more strikingly proved by taking an inverted syphon tube, one limb of which is 8 feet long and the other 1 foot, &c. He here proceeds to describe the construction and manner of using the instrument we have before mentioned as being that by the aid of which Boyle discovered the law.

It appears almost inconceivable that in sixteen years Mariotte should not have read the "Physico-Mechanical Experiments," in which we have seen Boyle so clearly suggested experiments on the subject in question, and it appears almost as inconceivable that in fourteen years* he should not have read the "Defence against Linus," containing not only the discovery of the law, but more elaborate experiments than he gives to illustrate and prove it. I find, however, no mention of Boyle's experiments in Mariotte's essay, at the same time he appears to be relating known facts rather than perfectly new and original experiments; it is curious, moreover, if he knew nothing of Boyle's experiments, that he should have used the same instrument, and directed it to be made of the same dimensions as those recommended by Boyle.

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* The author of the article on Mariotte in the "Biographie Universelle," (1820) writes—"Son discours sur l'air, qui parut en 1679 renferme une suite d'expériences intéressantes, alors àbsolument neuves." The "Nouvelle Biographie Générale," (1860,) on the other hand, states that the essay appeared in 1676. In the preface to Mariotte's collected works it is stated that the essays "On Plants," "On the Air" and "On Heat and Cold" appeared between 1676 and 1679. In the text I have given Mariotte the benefit of the earlier date.

† See "Oevres de M. Mariotte de la Academie Royale des Sciences." Paris, 1740.

But allowing that Mariotte discovered the law independently of Boyle, is priority of discovery nothing? Do we not know that it is everything in the present day? And if now why not two hundred years ago? Suppose a man were to discover a metal possessing as he believed, properties different from those of any known metal, that he published an account of it, and that it proved to be cæsium, should we, in speaking of the discovery of the latter, couple his name with Bunsen's? Most assuredly not, however laboriously he had worked, however elaborately his research had been carried out. It is the duty of every man, before commencing a research, to find out how much has been done by other experimenters; if this were done more completely, what a large amount of controversial matter would be excluded from scientific literature.

It is true that 200 years ago there were less opportunity of ascertaining the results obtained by other experimenters than in the present day; there was so little physical science in the world, Nature had for so short a time been interrogated by experiments, that many philosophers had a habit of believing everything they discovered was new, and did not trouble themselves to ascertain the results obtained by others, but surely in fourteen years Mariotte might have made himself thoroughly acquainted with all the important discoveries which had been made relative to the air.

I trust, on consideration of the above facts, it will be conceded that the law which affirms that the volume of a gas varies inversely as the pressure to which the gas is submitted, is not "the law of Mariotte," but "the law of Boyle.

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* It will be remembered that the "Physico-Mechanical Experiments" appeared in 1660, and the "Defence against Linus" in 1662.

(To be continued.)

Atmospheric Pressure as a Source of Mechanical Power.

To the Editor of the Journal of the Franklin Institute.

I am with your correspondent E. in his ideas and hopes of a popular motor from the atmosphere, assured as I am that seeking for it is not fishing for a one-eyed perch. In fact, the question is not so much, is it to be had, as what will it cost.

The subject of the forces, like that of natural history, extends to all things on the earth's surface and in her interior. They are represented as constituting two species, organic and inorganic; the former containing two distinct groups, animate and inanimate; and the whole pervading the mineral, vegetable and animal kingdoms. But, while thus diversified in their forms and functions, they are essentially one. That which animates a living organism is not itself organic. There are but two marked divisions, *mechanical* and *chemical*, and they are recognised on the ground of conventional use and facility of description and research.

Mechanical principles are limited and tolerably well understood, but while the theatres of their operations will become more and more enlarged, there is an increasing appeal to chemical science, and from it, doubtless the great novelties of the future are chiefly to come. In turning from physical to chemical forces, it is not to be supposed that the latter are more valuable *per se* than the former. In that respect all are alike, the effect of a certain amount of heat being the same, however evolved and applied—through aeriform, liquid or solid media. In nature's store-house all are labelled at one price, hence the advantages to be derived from one over another, arise from its better adaptation to some particular class of movements, to locations where the requisite materials are accessible, to where society is prepared for and in want of it.

We have no means to create force but only to transfer it from one body to another; and, as everything here is an embodiment of it, our common motors are first taken from those that readily yield it, as animals, wind, and running or falling water; next by changing the form of bodies, as solids into liquids and gases, and liquids into vapors. This is done by means of heat, which is not only a form but the primary form of terrestrial force; and, we should say, the constituent element of direct or positive force in every concrete sphere. Such spheres are the results of gravitation; that is, of condensation; while heat is the product of condensation and the universal agent of expansion. To diminish it in any body is to evolve a negative or contracting force. Deprived of heat in one form, it becomes an absorbent of it in another.

Of sources of mechanical power, there are none like the weight or pressure of the atmosphere in ubiquity or uniformity. Others are variable, some flitting and intermittent, most are local and some give out, but it never fails. In all climates, seasons and places, in all weathers, at all hours, it promptly responds to every call and will do so as long as the earth endures. Nor are we sure that there are any limits to its capacity as a mover of useful mechanism. All the demands that man can make on it, were they multiplied indefinitely, cannot affect its general or special functions in the economy of the planet an iota. Its power, like that of nature, is omnipresent and invariable, silent and invisible, bland and beneficent. It is not, however, likely to be fully appreciated for some time to come. There are not many who believe that this aerial envelope, which modifies solar heat and light, without which sound and music would be unknown, the vitalizing element of the vegetable and animal creation, which ministers to all our senses and sustains life, is competent to heighten its enjoyments by relieving us from physical drudgeries.

It has lately gone further and added a remarkable distinction between us and the tribes below us. They move in air and water by exerting their propelling organs against them, while we make the element we breathe act as a force to convey us through it without any muscular effort at all. Most certain it is, that a common force from the atmosphere, however and whenever obtained, will be hailed by the world as a worthy companion of steam. As chemistry must have a hand in it, it would be a brilliant addition to electrotype, the telegraph and photography.

There is a prevailing impression that atmospheric prime movers are hardly worth mentioning since Newcomen's time; that to commend them is to give weight to smoke, importance to trifles. Perhaps so, but let us look before leaping to that conclusion. Low steam then used to produce a vacuum became superseded by the expansive force of the vapor in the popular and justly popular high pressure engine. It is, however, consistent with this that atmospheric pressure may have work to do, appropriate to it without infringing on, or depreciating other motors. To those who have not made themselves familiar with the phenomena of steam, there is a fact bearing on this of very marked significance, viz: that the mechanical value of, or force to be derived from, steam is very nearly the same, under whatever temperature or pressure it be raised. This could not have been anticipated by practical men. To many it may still appear incredible that steam propelling a train of cars possess little, or no more value than the same quantity issuing from a tea-kettle spout, or from under the cover of a common pot.

The difference between the condensation of low, and the expansive force of high steam is thus given by Brande, as recognised results of English experiments: "To use round numbers, it may then be stated that by the evaporation of a cubic inch of water, a mechanical force is produced equivalent to a ton weight raised a foot high; and that this force is very near the same, whatever be the temperature or pressure under which the evaporation takes place." The following items from the voluminous table in the appendix to Lardner's work on the steam engine afford a sufficient explanation.

	Pressure in lbs. per sq. inch.	Corresponding Temperature.	Volumes of steam to that of water.	Mechanical effect of a cubic inch of water evaporated in lbs. raised 1 foot.
	1	102°1	20868	1739
	2	126°3	10874	1812
	3	141°6	7437	1859
Pressure of the atmosphere,	15	212°0	1700	2086
1 lb. on the safety valve,	16	216°3	1573	2097
2 lbs.	17	219°6	1488	2107
15 "	30	251°6	883	2209
35 "	50	283°2	554	2305
85 "	100	332°0	295	2462
185 "	200	387°3	158	2636

I have added the left hand column because there are those who do not perceive that there is any greater pressure in a boiler than what the safety valve indicates.

Without demonstrations like these it might have been thought that the mechanical value of a definite quantity of steam increased with its tension; and so it would if its volume did not diminish with the pressure. Thus, under 1 ℔. on the square inch its volume is over twenty thousand times that of the water from which it is evolved; at 2 ℔s. it shrinks into almost half that; at 15 ℔s. into one twelfth; at 50 ℔s. into a thirty-seventh; at 100 ℔s. into nearly a seventieth; at 200 ℔s. into a hundred and thirty-seventh.

Who could have foreseen that the work done by steam under a pressure of 200 ℔s. on the inch is not double that of the fluid under 1 ℔. in truth only half as much more. There are other attending singularities; the difference is extreme between using it to produce a vacuum under a piston and as a pushing force against it, yet how surprisingly alike the results. A high pressure engine acts against the atmosphere; against a force of 15 ℔s. on the inch, and this force is all that the other plan has; that which one rejects as a trifle and pushes aside as a nuisance constitutes the capital of the other, and a capital that yields an interest nearly equal to that of its popular opponent.

No better way of exciting and employing atmospheric pressure as a physical force has been devised than producing the vacuum under a piston, by admitting some substance beneath it while rising and expelling it as soon as the cylinder is filled. Fluid bodies are alone adapted for this, and, of permanent gases common air is the readiest and cheapest. Every where present it enters without trouble or cost. But how is it to be withdrawn? Not by mechanical force since more would be required than the vacuum could give in return, and no means have been discovered to condense it into a liquid. Recourse has been had to explosive gases and compounds, but they, besides being too costly, are in other respects inconvenient. They heat the cylinder, and what is worse, clog the piston. This might be avoided by using the blast somewhat prolonged, outside of the cylinder on the principle exemplified in the paper on increasing the blasts of bellows, published in the Journal for May, 1858. If gun cotton could be thus successfully employed, it would give us the neatest and cleanest of portable forces. See also Ewbank's Hydraulics 489-491 for vacua of over 20 inches of mercury by currents of steam.

Another mode is exhibited in the old experiment of holding a slip of lighted paper under an inverted tea cup and dropping it into a saucer of water, or as air is driven out of a cupping glass by a piece of cotton dipped in alcohol. There can be little difficulty in applying the principle to an engine, and if petroleum oils are going to be as abundant as appearances promise, an available force, with some modifications of the apparatus may be obtained.

But vapors that resume the liquid form at common temperatures are deemed the most promising. Liquids which boil at low degrees of heat would seem the best, but there are other conditions to be observed, as the volume, density, and cost of the vapor. The three liquids in the annexed table exhibit some striking differences. The first can be had for nothing, the second for from two to three dollars a gallon—before the war from 50 to 75 cents—while the price of the last ranges too high at present to be thought of.

Liquids.	Boiling Point.	Volumes of Vapor to one of Liquid.	Density of the vapor, air being 1.
Water,	212°	1700	625
Alcohol,	176°	660	1613
Ether,	96°	443	2586

The density of alcohol being more than 2½ times that of steam, if it would answer to charge a cylinder only half full and that were to expand and adequately fill it, something might be gained; the liquid, of course, being used over and over without waste. It is doubtful, however, that water can at present be superseded. Evaporating at ordinary temperatures, it boils at 212°. For the purpose in question, no higher temperature is wanted. Rather a lower one, if possible; and, as ebullition does not affect the nature of steam, but simply increases its evolution, it is worth while to inquire if that cannot be done to some extent, mechanically, by agitation for example, as when cooks stir up the contents of their caldrons.

A large portion of the early formed globules or vesicles never reach the surface of the water, being ruptured or condensed on their way up. They are being evolved when a kettle is said to simmer or sing, but not till the whole of the liquid is heated to 212° do they rise without, more or less, being condensed. It has been found that when a vessel has just stopped boiling, if little angular pieces of metal be dropped in, ebullition is renewed. The points afford bases for and facilitate their formation, hence it may, I think, be taken for granted that the suspension in the water of a mass of metallic spiculæ, or other jagged bodies, would materially hasten their evolution and ascent. It would tend to supply a cylinder with saturated vapor, that which is most readily condensed, and of the lowest temperature. But whatever the latter might be I would cut off the supply before the piston reached the top of the cylinder. The small force thus expended, would be made up by the attenuation of the fluid, a less amount of heat to be abstracted and a quicker condensation. Would it not be an advantage to make the piston thus initiate the vacuum; predisposing, as it were the vapor for collapsion? To accomplish that with the smallest quantity of the cooling agent, I would make the parts on which the steam acts as thin and light as possible.

Watt was so embarrassed and baffled by the amount of metal in his cylinders and pistons, bed-plates and side pipes, that he was driven to effect condensation in a separate vessel. The first steam engines were exceedingly massive. Such was the one he made for Fulton's first boat. With it I was familiar, while it remained in the factory at Powless Hook after his death. It is no wonder that Watt became, as we are told, forcibly impressed with the waste and expense of steam and fuel in the operation of condensation. In the theory of the atmospheric engine, one cylinderful of steam should suffice for each stroke of the piston, whereas he found the actual consumption was four to five cylinderfuls per stroke. Nor was this all. On examination he discovered the source of this waste to arise from the necessity in order to make the piston ascend, not only to condense the steam *but to cool the whole mass of the cylinder down to* 100°, and to make the piston descend it was necessary not only to fill the cylinder with steam, but to *raise the temperature of cylinder and piston from* 100° *to* 212°.

He had other obstacles to overcome. His engine was so far in advance of the mechanical capabilities of the age that it was with the greatest difficulty it could be executed. Smeaton thought it could never be introduced into general use on that account. The cylinders were often wider at one end than the other. Speaking of an 18-inch one, Watt says, in a letter, that the longest diameter exceeded the short one $\frac{3}{8}$ of an inch! It was not till then that the revolution in working metals began by a revolution in tools. There were no self-acting ones. Slide rests and planing machines unknown; everything being executed by hand. See Smiles' "Industrial Biography: Iron workers and tool makers."

Watt got rid of his condensing troubles but it was at the expense of additional machinery and a large outlay of force to work it. According to Lardner *four-tenths* of the mechanical force of both condensing and non-condensing steam engines are intercepted and consumed by them, leaving only six-tenths available. He enumerates friction and cooling of the steam in passing to the cylinder, radiation of heat from it and its appendages, friction of the piston, loss by leakage, force expended on expelling the steam after its action on the piston, force to open and close the several valves, to pump up water for condensation, and to work the air-pump. It seems scarcely possible that an atmospheric engine can intercept 14, much less 40 per cent. of its power.

Qy. What did Watt gain in power, by his separate condenser? Was not the expense of working it equal to the three or four cylinderfuls of steam consumed on the previous plan?

As for agents of condensation it is not easy to suggest anything new. I once thought of naming, with the view of enlarging the range of inquiry, jets of an hydrous vaporsor liquids to induce coalescence of the globules, or puffs of some deliquescent powders to hasten liquefaction. Then the idea that possibly something might be added to water to render it more readily evaporable. If we had ample means promptly to liquefy aqueous vapor, there would be no occasion to be so particular about keeping down its temperature, and that such are to be found in Nature's laboratory, it is said, there is no doubt as the most ardent inquirers have but barely entered it—that of her resources nothing is known compared to what is to be known—that chemistry progressing we shall have as cheap a source of cold as we have of heat, and that *then* atmospheric motors may become common.

The problem is then one of heat and cold—alternate changes of one to the other. Were this all we should have only to wait till the atmosphere abstracted the heat through the sides of the cylinder, but the operation would be too slow, hence, time is an element in the solution. Whatever number of downward strokes the piston is required to make per minute, just so many times must the steam enter and be chilled back into water. Now, before appealing to, or waiting for, chemists, if we look out on what nature has done already, we shall have to take to ourselves a rebuke addressed to another people. "Ye see indeed but perceive not." She has established a periodical frigorific supply almost as abundant as water, and with no greater tax on it. It is offered us *ad libitum* and for nothing. We cannot have anything cheaper than steam to charge a cylinder, and what is there in greater plenty in these latitudes than *ice* to condense it. During the summer it has been and is now (October), being delivered at our houses for 30 cents per 100 lbs. By the quantity it may, we presume, be laid up at little over a dollar per ton, in some places for less. We have thus in the opposite conditions of one substance, and readily convertible into each other, both the desired elements for exciting atmospheric pressure, and that substance gratuitous and most profusely differ. What more can be hoped for? It is folly to wait for something better than ice, and as for science ever furnishing anything equal to it on the same terms, it is worse than folly to expect.

It perhaps will be thought, if there is such virtue in ice it would have been brought forward long ago and be in extensive use now. That does not follow. Innumerable things are obvious to sight, the future uses of which are not discerned. The case is one of those which show how in the arts one thing is the sequence of another. Ice has only lately become an article of merchandise. But for the fact that as regular a trade in it has been established as in coal and other things of daily consumption, it had probably not yet been thought of as an element in the generation of force.

The amount of heat necessary to evaporate a certain quantity of water is about the same under all pressures. The difference lies here between a steam engine and an atmospheric one;—the former throws into the air at every stroke the hot contents of the cylinder. According to some writers 90 per cent. of the heat and consequently of the fuel is wasted—not 10 per cent. utilized. Hence a continual flow of fresh water into the boiler. With the latter the water is merely kept boiling as in an open vessel and the condensed steam runs back into it at a temperature of 100°. There is no discharge of waste heat except what the ice and ice-water takes up. The amount of fuel is therefore nominal compared to that of a steam engine, and so is the size of the boiler. One little larger than a domestic caldron should suffice for one or two horse power.

The quantity of water required for the boiler is readily determined.

Suppose the working cylinder of the capacity of a cubic foot, the area of the piston 144 inches, and a 12-inch stroke. The pressure on the piston would be 2160 lbs. and this moving at the rate of a fraction over 15 feet per minute would reach the standard of horse power ; so that 15 cubic inches of water—less than half a pint—would have to be evaporated every minute for each horse power.

The quantity for liquefaction of the steam is a great deal more. If a cubic inch of water in the form of steam at 212° be introduced into the same vessel with 5½ cubic inches of ice-cold water, the result will be 6½ cubic inches of water at 212°. Hence steam at 212°, requires 5½ times the water in it to reduce it into water at the boiling point, and an additional quantity to reduce it to 100°. It is found in practice, says the Encyc. Britannica, that the most economical vacuum for English Steam Condensing Engines varies, according to the pressure from 95° to 105° equal to 26 and 27½ inches of mercury when the barometer is at 29½ inches, and that not less than twenty times the water in the steam is required to condense it. This large quantity—20 cubic inches to a cubic foot—is, however, used at the common temperature of 50°. If atmospheric engines required so much we should have but feeble hopes of them.

To sustain a proposition in favor of ice as a condensing agent something more will be expected than its profusion and little cost. To secure its adoption it should be more efficacious than water and a less quantity required. The following facts leave no room for doubt on these points. The singular difference in the cooling power of water in its liquid and solid forms is of course accounted for by a less amount of latent heat in one state than in the other.

If one pound of water at 174° be added to another pound at 32°, the result is two pounds at 87° (just half of 174°). But a pound of water at 174° added to a pound of ice produces two pounds at 32°. That is, ice-cold water lowers the temperature 87 and ice 142°. To test this I have taken advantage of the presence of snow. One day, the air at 36° and the snow soft, a pound of water at 32° and another at 174° gave two pounds at 100°, while snow in place of cold water reduced the mixture to 44°. Another day to 36°, the snow being hard and icy. The temperature of a pound of boiling water and another at 32° was 108°. With snow in place of the cold water it was 36°. The mean of three experiments with half a pound of icy snow to a pound of boiling water was 98°.

Such is the difference between using ice and ice-cold water, but as jets of condensing engines, given at the common temperature of 50°, instead of 32° the difference is still greater. Allowing a liberal margin, may it not be inferred that one-third of water in ice and snow will be as effective in atmospheric as three-thirds of the liquids are in common condensing engines.

It will perhaps be objected that to apply a solid body like ice, or a semi-solid one like snow in the manner of a jet is not to be easily done. True, but showers of pulverized ice are not impossible things in the face of their acknowledged superior effects.

Modes of applying the cooling agent:—Could an external application of it be made to answer, there would be no waste of water from the boiler and no trouble with it after being once charged. The process might apply to alcohol and ether but hardly to steam at present. Still it may be among the possibilities.

An internal application necessitates a discharge of warm water from the cylinder at every descent of the piston except what is returned to the boiler. Of two modes of internal condensing, a descending shower through a piston made hollow and the lower plate finely perforated (as in an experimental model) and a jet from below, the first has its advantages but the latter is perhaps the most efficient, as it rises and falls in the vapor and therefore has a better chance of allowing less to escape contact with it. With a descending shower cylinders would have to be vertical and all things considered, that seems the best position for them; still circumstances may require them to be used horizontally.

As every machine is a vehicle of force, that which it absorbs is so much deducted from its available power. Thus the heat taken up by the cylinder and piston is, as already seen, a clear loss in itself and incurs an additional one in ice to abstract it. It would be well to make the acting parts of, or to case them with, a material that absorbs neither heat nor moisture, that there may be nothing but the steam to be cooled. Large syringes are now made of vulcanized rubber and bear a temperature of between 300° and 400°.

Steam, like other motive agents, has no means within itself to increase or diminish its energy, hence we add fuel to a boiler as we add power to a lever, and it remains for experiment to determine the comparative value of high pressure and atmospheric engines by ascertaining whether the additional fuel and accessories with resistance to the atmosphere, in one class, be less or more than the ice and its accessories with no resistance from the atmosphere in the other. But on whichever side the cost preponderates, or if on neither, there are, and always will be occasions, circumstances, or places, where one should have the preference. This is a provision of nature that applies to all forces.

High pressure engines waste more heat than others but they are preferred as common motors because they possess advantages that pay for the waste. They are more compact in their working parts and more energetic than atmospheric ones of the same dimensions can ever be. They will continue special favorites where fuel abounds. Among openings for others—Agriculture presents one. It wants a movable engine not exceeding half the weight and cost of a steam locomotive. An atmospheric one would be an invaluable acquisition to planters.

And what objections can be urged against placing the mechanism on city railway cars? None as to safety since explosion of the small boilers would be impossible. The ruling consideration is economy. The working cost will be in the ice and coal. The amount consumed of the latter for each car during 12 hours will be comparatively small, and as for the ice, supposing a car use up two tons in that time its cost would not exceed three or four dollars at most. It would of course, be taken up in parcels every two or three trips like a steam locomotive taking in water, of which they would require none.

In high latitudes where firing materials are few and sparse, atmospheric motors may become common, while steam will be the general one in temperate and tropical zones and wherever fuel is plenteous. I see no improbability in ice becoming one of the means, as an agent of force, of equalizing the extremes of national conditions.

Physical force is indispensable to social progress. As long as men have none but their own they cannot rise out of barbarism. Those of the Arctic regions would seem to be the last to possess inorganic forces, but when they learn that ice can be used as an adjunct of heat in their evolution, they will have a still higher estimate of their great staple of it and snow, and furnish another illustration of the principle of compensation—so remarkable in the organization of animals but which extends to climates, their products and people. *

(To be Continued.)

Exposition of the late Researches on the Cohesion Figures of Liquids.

By Thomas Thethill Wright, M. D.

From the Journal of the Society of Arts, No. 631.

Dr. Wright stated that, on being requested to give one of the "Special Discourses to the Society of Arts," he had chosen the subject of the "Cohesion Figures of Fluids," as he was desirous of bringing before the practical men assembled at the meeting the remarkable researches of Tomlinson, as well as observations made by himself in the same field. The lecturer then proceeded to give a very full exposition of Tomlinson's discoveries, with numerous carefully executed drawings of the cohesion figures of various oils and other fluids when dropped upon surfaces of water and other liquids, figures which have already been exhibited by their discoverer at the Society of Arts in London, in his paper read before it. Dr. Wright then proceeded to describe two new classes of cohesion figures discovered by himself:—1st. Figures produced on perfectly clear and freshly split surfaces of mica; and 2d. Figures produced by drops of fluid on surfaces of mica or glass, when connected with the poles of an induction coil. He showed by the oxy-hydrogen lantern, on a screen twelve feet in diameter, images of both of these classes of figures, as well as numerous drawings of microscopic figures which were too small to appear on the screen. The mica figures were produced by placing a large drop of fluid, (sulphuric acid, nitric acid, tinctures of iodine, henbane, vegetable infusions, and a great variety of animal fluid and mixtures of them) on the surface of the mica, and gently breathing on them, when the cohesion figures instantly developed themselves in an infinite variety of forms. Those shown on the screen consisted of an infusion of the extracts of belladonna, senna, and hemlock, and of healthy urine, urine containing bile, and urine containing albumen. These figures were rendered visible, developed as it were, by dusting them with a powder puff containing hair powder or the finest lampblack. Dr. Wright pointed out that all these figures presented a distinctly bisymmetrical form, and imitated, with remarkable clearness, the forms of various microscopic algæ and diatoms; while some of the images of urine, developed with carbon, in addition to their branching forms, were minutely veined, so as to resemble the finest specimens of agate. The second class of figures—the electric cohesion of figures*—differed entirely with the fluid used, the surface on which it was placed (whether glass or mica), the intensity of the electric current, and the pole (whether positive or negative) by which the fluid was electrized. Very splendid and large figures were made on chemically clean plate-glass by powerful induction coils. But the greatest variety of figures occurred when the thinnest microscopic glass and mica were employed, with a small induction coil, giving a spark of about a tenth of an inch. The electric figures on mica differed entirely from those on glass; and those on mica freshly split from those on mica washed, heated or exposed to the air; in fact the slightest change in the character of the fluid, or the surface on which it was dropped, resulted in the production of difference of figures. The electric figures projected on the screen imitated curious forms and species of Ulva, Ceramium, Delesseria, and finely branched lycopodiums. Dr. Wright stated that in these cohesive figures of Tomlinson and himself, the pattern designer possessed a source of infinite diversity of form, free from the stiffness of the designs furnished by the kaleidescope of Brewster. Many of the figures in mica glowed with all the gorgeous tints of the soap bubble.

At the close of the discourse, his grace the Duke of Argyll moved a special vote of thanks to Dr. Wright for his admirable exposition, which was seconded by Dr. Stevenson Macadam, and unanimously agreed to.

Pro. Roy. Scottish Soc. of Arts.

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* In producing the electric cohesion figures, a plate of brass is laid on the table, and covered with a sheet of black paper dripping in a solution of chloride of calcium; on this the glass plate is laid, and in the centre of the glass plate the minute drop of fluid to be electrized. One pole of the induction coil is connected with the brass plate, the other with the drop. The figures instantly shoot out as soon as the induction coil break is set in motion.

Bituminized Paper Pipes, and Roof Sheeting.

From the Practical Mechanics' Journal, November, 1864.

These pipes are made on a cylinder of which the diameter is the required bore of the pipe; the paper is rolled in widths equal to the required length of the pipe, and passes through molten bitumen, until the required thickness of pipe is attained. Acting in connexion with this, another cylinder revolves against the first cylinder bearing the bituminized paper, the latter being thus subjected to a very great pressure, which causes a regular distribution of bitumen. When the pipe is taken off the cylinder, the inner surface is coated with an indissoluble water-tight composition, and the outer surface is coated with bitumen mixed with sand. The compressed paper, without the molten bitumen forms one-third of thickness of the pipe. The great advantage of these pipes consists in their *resistance to internal and external pressure.* Their power of resistance is sufficient to withstand a pressure of more than 240 pounds to the square inch, or 15 *atmospheres*, equal to more than the pressure of a column of water 500 feet in height. In Hanover and Paris, where experiments were made with these pipes in reference to their resisting power, they withstood a pressure at the former city of more than 24 *atmospheres*, equal to about a column of water 800 feet in height, and in the latter city they withstood a pressure of more than 500 pounds on the square inch, equal to about a column of water 1000 *feet in height.* In making these trials not only one pipe, but several joined together were tested. As above stated the resisting power of the pipes can be considerably augmented by adding to the thickness. The manufacturers undertake to furnish pipes to resist a pressure of 600 pounds on the square inch. Judging from the experiments made by Mr. Samuel Hughes, Civil Engineer of London, and others, the resistance to external pressure of the bituminized pipes is so great that they can with perfect safety be laid under any depth of causeway, and bear equal or unequal pressure.

Durability.—The known property of asphalt to resist atmospheric changes, renders it most valuable for pavements and roofing, whilst when applied to pipes, exposed as a rule to the humidity of the soil only, it must augment their durability to an almost unlimited degree. Iron pipes are nearly always coated with asphalt to increase their durability and protect them, but the paper pipes, being composed in a great measure, throughout their substance of this material, must have a great advantage over them. More than ten years experience shows, besides, that paper pipes that were laid in Paris in the year 1851, when taken up were found to be in the same state as when laid down. As these pipes do not suffer either from concussion or frost, and are not liable to leakage or oxidation, (the causes of destruction to metal pipes,) their durability must needs be almost unlimited. *Impermeability.*—By the above described mode of manufacturing, a perfect homogeneous substance is attained, and the density of the bituminized material is greater than that of all other kinds of pipes. *Bitumen a Bad Conductor.*—Bitumen being a bad conductor protects the water in these pipes from excessive cold in winter, and in summer from heat; this same peculiarity farther leaves the length of the pipes unaltered by the change of temperature; this is not the case with metal pipes. *The inoxidability* of the bituminized paper pipes is another circumstance greatly in favor of their use as a substitute for iron tubes. Such inconveniences as destruction or obstruction by oxide, noxious chemical alterations of water, as in the case of leaden water pipes, impregnation of the water with oxide of iron, so very injurious for many purposes cannot take place with the use of tubes made from bituminized paper, neither is there the most trifling impurity imparted to the water passing through them.—*Bitumen unaffected by Acids and Alkalies.*—The bitumen pipes are not affected by acids or alkalies, and remain perfectly unimpaired when water, impregnated with acids or alkalies, is led through them. Metal pipes, on the contrary, are subject to rapid decomposition when placed in sulphuric acid, chalk soil, or copperas in solution, frequently found in coal-pits and mines.—*Non-conductor of Electricity.*—Through the peculiarity of bitumen not being acted upon by acids, and being a non-conductor of electricity, the bituminized pipes are not liable to destruction and stoppage, as iron pipes are in which galvanic streams are frequently produced, causing leakage and oxidization. In virtue of this peculiarity, asphalt pipes will be used with advantage for underground telegraph wires, through tunnels, and under bridges.—*Elasticity.*—The elasticity of these pipes protects the same from bursting by external shocks or concussions, which causes most of the other kinds of pipes to break, the capability, also, of extension is greater than the expansion caused by frozen water, hence bursting is avoided, an accident to which all other pipes are liable.—*Specific Gravity.*--The specific gravity of these pipes, compared to iron pipes, is as 1 to 5, which circumstance, as it facilitates transport and adjustment, considerably reduces the cost.—*Cheapness.*—In great Britain, where all kinds of metal pipes are undoubtedly manufactured cheaper than anywhere else, the bitumen pipes, when laid, are still only one-fourth the cost of lead, and about one-half the cost of iron. On account of their great lightness, the rate for transport is comparatively very small—say only one-third of the cost of transport for iron pipes. In conclusion, it may be mentioned, that all workings, repairs, &c., of bituminized pipes are much easier executed and at less expense than is the case with other pipes. The following bituminized pipes are manufactured in seven feet lengths. *A.* Water pipes to withstand the pressure of 15 atmospheres, either with bituminized couplings or with iron flanges. *B.* Gas pipes (lined with metal to resist the chemical influence of gas) with iron flanges. *C.* Air pipes for mining purposes, of lighter construction, and connected by bituminized couplings.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, February 16th, 1865.

John H. Towne, Vice President in the chair.

The minutes of the last meeting were read and approved.

The Board of Managers reported donations to the Library from

The Royal Astronomical Society, and the Society of Arts, London; the Canadian Institute Toronto, and Major L. A. Huguet-Latour, Montreal, Canada; Prof. A. Dallas Bache, and Frederick Emmerick, Esq., Washington, D.C.; the Legislature of Pennsylvania, Harrisburg, and Prof. John F. Frazer, Philadelphia.

The Special Committees on Steam Expansion; and on Weights, Measures, and Coinage of the United States, reported progress, and the Institute having been notified of the resignation of Mr. Briggs, chairman of the last mentioned Committee, the Secretary was by motion directed to call the said Committee together. The Special Committee on an Uniform System of Screw Threads, &c., reported:—

That they had distributed 250 copies of their former report, accompanied by a circular letter and copy of Mr. Wm. Sellers' original paper upon the subject; to the individuals, companies, and government officials, interested in the matter, and anticipated soon to receive communications in return. Some remarks were then made upon the report of the Committee by Mr. Caleb P. Jones, relative to the diameter of nuts, and further consideration of the subject was then deferred until the next meeting.

The Special Committee to draft petition to the City Councils relative to the appointment of inspectors of Steam Boilers in the City of Philadelphia, reported progress.

The following Committees were then appointed by the President:—

On the Library.

Henry Ames,
Pliny E. Chase,
James H. Cresson,
James Dougherty,
John Ferguson,
George Harding,
John Hoskins,
James T. Lukens,
Henry Morton,
Henry G. Morris.

On Arts and Manufactures.

William Adamson,
John H. Cooper,
Charles G. Crane,
Henry R. Lawrence,
C. Eugene Meyer,
Jacob Naylor,
Isidore Osorio,
Percival Roberts,
William G. Rhoads,
Samuel S. White.

On Minerals.

Clarence S. Bement,
Isaac H. Conrad,
John F. Frazer,
Emile Geyelin,
J. Peter Lesley,
Robert H. Lamborn,
Robert E. Rogers,
Colman Sellers,
Richard A. Tilghman,
Elias Wildman.

On Exhibitions.

John C. Cresson,
James H. Cresson,
John Gardiner, Jr.
Edwin Greble,
Bloomfield H. Moore,
J. Vaughan Merrick,
William A. Mitchell,
T. Morris Perot,
John H. Towne,
O. Howard Wilson.

On Models.

James Agnew,
William B. Bement,
Edward Brown,
Charles H. Cramp,
Mordecai H. Haines,
Addison Hutton,
John Kile,
W. Barnet Le Van,
John L. Perkins,
S. Lloyd Wiegand.

On Meteorology.

Charles M. Cresson,
John F. Frazer,
Henry Hartshorne,
Caleb S. Hallowell,
James A. Kirkpatrick,
Henry Morton,
James A. Meigs,
Fairman Rogers,
James S. Whitney,
Samuel S. White.

On Meetings.

B. Henry Bartol,
Henry Cartwright,
John F. Frazer,
Henry Howson,
Edward Longstreth,
J. Vaughan Merrick,
Henry Morton,
Fairman Rogers,
Coleman Sellers,
Thomas Shaw.

On Scientific Proceedings of the Institute.

John F. Frazer,
J. Vaughan Merrick,
Henry Morton,
Fairman Rogers,
Coleman Sellers.

The Secretary then read his report on new inventions and discoveries. In this reference was first made under the head of *Mechanics*, to various machines lately introduced for the purpose of boring deep wells for water or oil; for cutting or digging coal by steam power; and for pumping or otherwise raising fluid material from great depths. Under the head of *Physics*, reference was made to certain improvements in tempering of steel, by the use of a highly conducting bath, as for example one of mercury, by which a higher degree of hardness was attained (with less intense heating, and consequent warping), than in the usual method. A series of tubes filled with various gases and vapórs, exhausted to a certain point of rarefaction and then hermetically sealed, were then exhibited, with the Ruhmkorff coil. The flashes of statical electricity developed by that instrument being caused to pass through these tubes, (from platina wires melted into their ends when they were first being prepared), developed in them most brilliant flashes, streams, and clouds of colored light, crimson violet and blue, crossed in many cases by transverse dark bands, while the substance of the tubes themselves became luminous by *fluorescence* with tints of blue, yellow, or green, according as the glass contained, potash, soda, or a mixture of both.

One of these tubes also exhibited in a most striking manner the property of phosphorescence, remaining luminous and visible for many seconds after the cessation of the electric discharge.

These tubes (known from their constructor as "Geissler tubes"), it was to be remarked were not new inventions in themselves, but were here introduced as a novelty, because never before exhibited in any way in this city or its vicinity. The set of tubes employed were the property of Mr. Charles N. Bancker to whose kindness the Institute was indebted for the pleasure of inspecting them.

Under the head of *Chemistry* reference was made to the establishment by Meissner, of Ant-Ozone as an alotropic condition of Oxygen;—to the power which Ozone possesses of arresting vegetable growth and the relation between this growth and the putrefaction of animal matter;—to the delicate test for free Phosphorus furnished by its green coloration of the flame of hydrogen generated in its presence, especially when the temperature of the flame was reduced by the introduction of a solid good conductor, such as a mass of iron, lead or the like;—to the extraction of gold from poor ores by nascent Chlorine, &c.

Mr. Sellers then made some remarks upon the employment of the fluorescent properties of certain kinds of glass in the analysis of light, especially with reference to its photographic powers.

An outline was then given of the lecture on Light which it is proposed to deliver before the Institute at the Academy of Music, and on motion the meeting was adjourned.

HENRY MORTON, *Secretary.*

A Comparison of some of the Meteorological Phenomena of FEBRUARY, 1865, *with those of* FEBRUARY, 1864, *and of the same month for* FOURTEEN *years, at Phila., Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	February, 1865.	February, 1864.	February, for 14 years.
Thermometer—Highest—degree, .	56·00°	57·00°	70·00°
" date, .	26th.	28th.	23d, 1860.
Warmest day—Mean,	49·17	49·67	59·30
" " date,	26th.	28th.	25th, 1857.
Lowest—degree, .	3·50	4·00	—1·00
" date, . .	13th.	17th.	7th'55;8th'61
Coldest day—Mean,	12·00	7·00	4·50
" " date, .	13th.	17th.	6th, 1855.
Mean daily oscillation,	11·34	15·29	13·40
" " range, .	5·97	7·18	7·21
Means at 7 A. M., .	28·45	30·55	29·29
" 2 P. M., .	36·20	40·57	38·38
" 9 P. M., .	32·44	34·74	33·45
" for the month,	32·36	35·29	33·71
Barometer—Highest— Inches, .	30·322 in.	30·375 in.	30·671 in.
" date, . .	21st.	19th.	4th, 1863
Greatest mean daily press.	30·293	30·267	30·595
" date, . .	21st.	18th.	12th, 1857.
Lowest—Inches, . .	29·256	29·284	29·065
" date, . .	8th.	16th.	23d, 1853.
Least mean daily press.,	29·347	29·383	29·227
" date, . .	8th.	16th.	16th, 1856.
Mean daily range, .	0·205	0·182	0·220
Means at 7 A. M., .	29·872	29·792	29·916
" 2 P. M., .	29·849	29·742	29·869
" 9 P. M., .	29·875	29·796	29·902
" for the month,	29·865	29·777	29·896
Force of Vapor—Greatest—Inches,	0·326 in.	0·262 in.	0·549 in.
" date, .	26th.	1st.	16th, 1857.
Least—Inches, .	·044	·022	·013
" date, .	13th.	17th.	6th, 1855.
Means at 7 A. M.,	·124	·132	·138
" 2 P. M.,	·134	·124	·158
" 9 P. M.,	·137	·139	·156
" for the month,	·132	·132	·151
Relative Humidity—Greatest—per ct.,	100·0 per ct.	90·0 per ct.	100·0 per ct.
" date,	23d.	6th.	often.
Least—per ct.,	35·0	20·0	20·0
" date, .	24th.	22d.	22d, 1864.
Means at 7 A. M.,	75·1	70·1	78·4
" 2 P. M.,	61·4	46·6	63·1
" 9 P. M.,	71·7	63·8	75·1
for the month,	69·3	60·2	72·2
Clouds—Number of clear days,* .	8	10	8·1
" cloudy days, .	20	19	20·
Means of sky cov'd at 7 A. M.	58·2 per c.	50·7 per c.	61·4 per c.
" " " 2 P. M.	58·9	63·1	60·8
" " " 9 P. M.	61·8	47·6	48·2
" " for the month,	59·6	53·8	56·8
Rain and melted Snow—Amount,	5·491 in.	0·697 in.	2·927 in.
No. of days on which Rain or Snow fell,	10·	5·	10·
Prevailing Winds—Times in 1000,	N65°18′W·351	S80°41′W·379	N72°17′W·288

*Sky, one-third or less covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of the WINTER, of 1864–65, *with that of* 1863–64, *and of the same Season for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	Winter, 1864–65.	Winter, 1863–64.	Winter, for 14 years.
Thermometer—Highest—degree, .	59·00°	65·00°	71·00°
“ date, .	Dec. 7th.	Jan. 29th.	Dec. 2, 1859.
Warmest day—Mean,	52·33	54·17	62·80
“ “ date,	Dec. 3d.	Dec. 13th.	Dec. 19, ’56
Lowest—degree, .	3·50	4·00	—5·50
“ date, .	Feb. 13th.	Feb. 17th.	Jan. 23, ’57
Coldest day—Mean,	12·00	7·00	—1·00
“ “ date, .	Feb. 13th.	Feb. 17th.	Fe. 7,’55; Fe.8,’61.
Mean daily oscillation,	11·02	14·10	12·53
“ “ range, .	6·83	6·52	6·73
Means at 7 A.M , .	28·07	30·44	29·62
“ 2 P.M., .	34·89	39·06	37·62
“ 9 P.M., .	31·75	33·89	33·09
“ for the Winter,	31·57	34·46	33·44
Barometer—Highest—Inches, .	30·411 in.	30·495 in.	30·704 in.
“ date, . .	Dec. 9th.	Dec. 7th.	Jan. 28, ’53
Greatest mean daily press.	30·362	30·423	30·611
“ date, . .	Dec. 9th.	Dec. 7th.	Dec. 18, ’56
Lowest—Inches, .	29·071	29·167	28·941
“ date, . .	Dec. 21st.	Dec 14th.	Jan. 23, ’53
Least mean daily press.,	29·275	29·341	29·086
“ date, . .	Dec. 21st.	Dec. 14th.	Jan. 23, ’53
Mean daily range, .	0·235	0·204	0·218
Means at 7 A.M., .	29·839	29·892	29·941
“ 2 P.M., .	29·791	29·841	29·897
“ 9 P.M., .	29·828	29·897	29·927
“ for the Winter,	29·819	29·877	29·922
Force of Vapor—Greatest—Inches,	0·438 in.	0·486 in.	0·551 in.
“ date, .	Dec. 7th.	Dec. 14th.	Dec. 2, 1859.
Least—Inches, .	·044	·022	·013
“ date, .	Feb. 13th.	Feb. 17th.	Feb. 6, 1855.
Means at 7 A.M., .	·127	·136	·138
“ 2 P.M., .	·136	·139	·158
“ 9 P.M., .	·142	·141	·152
“ for the Winter,	·135	·139	·148
Relative Humidity—Greatest—per ct.,	100·0 per ct.	100 per ct.	100 per ct.
“ date,	Feb. 23d.	Jan. 18th.	often.
Least—per ct.,	26·0	20·0	20·0
“ date, .	Dec. 1st.	Feb. 22d.	Feb. 22, ’64
Means at 7 A.M.,	77·8	72·4	78·5
“ 2 P.M.,	63·8	54·7	65·4
“ 9 P.M.,	74·0	67·3	75·5
“ for the Winter,	71·9	64·8	73·1
Clouds—Number of clear days,* .	20	33	25·7
“ cloudy days, ·	70	58	64·5
Means of sky cov’d at 7 A.M.,	60·5 per ct.	55·6 per ct.	62·7 per ct.
“ “ “ 2 P.M.,	67·5	57·6	62·6
“ “ “ 9 P.M.,	61·7	45·5	48·3
“ “ for the Winter,	63·2	52·9	57·8
Rain and melted Snow—Amount,	13·843 in.	7·446 in.	9·901 in.
No. days on which Rain or Snow fell,	41·	25·	31·4
Prevailing Winds—Times in 1000	N75° 7′W ·267	N85° 5′W ·306	N65° 3′W ·293

* Sky one-third or less covered at the hours of observation.

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FOR THE

PROMOTION OF THE MECHANIC ARTS.

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CIVIL ENGINEERING.

On the Mechanical conditions of Railway working to prevent Destructive Wear and Risk. By W. Bridges Adams.

From the Journal of the Society of Arts, No. 628.

Continued from page 164.

Having obtained successful results in the elastic action both of wheels and rails, the next question was to obtain a true mechanical action in the movement of wheels and axles. As far back as the year 1837 the writer had sought to impress upon railway authorities the importance of radial movement in the axles, enabling them to run at a right angle with the rails, whether on straight lines or curves, and proposed various modes of accomplishing it, but he could get no attention. The railways were made in what were called straight lines, though practically crooked lines, and it was taken for granted that the coning of the wheel tires accomplished all that was wished. But in America crooked lines obtained with very sharp curves, in order to go around street corners instead of outside the towns, and a bell was suspended at the entrance, to be struck by the engine, and a notice painted on a maple slab, "Look out for the locomotive, when the bell rings." To facilitate the movement of the engine round the curves, the front end was provided with a swiveling truck, called a bogy, analogous to the ordinary under-carriage of a road vehicle, moving on a centre pin, but with four wheels instead of two, the wheels being guided by their flanges against the rails instead of by a pole. This was so convenient, that it came into general use in America, and it was first introduced into England on the Birmingham and Gloucester line, the engines being made in America. But it was defective in principle. In ordinary under-carriages on the road, the length of the pole steadies the wheels. In the four-wheel bogy, the distance between the front and back wheels was less than the width between the rails, and, consequently, swiveling on the centre pin, the bogy was apt to run unsteadily, and drag the wheel flanges against the rails, the contact with the outer rail on curves setting the axles askew to the rails. This evil was continued on the South Devon line, where, the sharp curves necessitating the use of the bogy, it was applied on a seven feet gauge with the wheel centres five feet apart. In addition to this defect, apparently resorted to, to compensate in some measure for the fixed parallelism of the axles, it did not in any way help the skew position of the driving wheels, as the central pivot did not permit lateral movement of the bogy. To remedy this Mr. Bissell, in America, devised a plan of removing the centre pivot from midway between the four wheels to a point between the driver and the bogy; thus the movement of the wheels became radial, or in the circumference of a circle, instead of the centre. This was a plan on which the writer had built road carriages long previously, under the name of Equirotal carriages, and had proposed to apply the principle to engines. Mr. Bissell subsequently applied the same principle to engines with two wheel bogies, and time and circumstances having forced on the attention of English engineers the necessity for radial movement, other attempts were made to correct the defects of the bogy, and one was by providing a lateral slide as well as pivot movement to the centre. But on this plan the guidance was lost, and it was not found to answer.

Seeing that the time was approaching for more perfect machinery and for radiating axles, the writer again set to work to simplify the structure. Abandoning the truck form, or bogy, altogether, the axle boxes were adapted to slide in curved lines laterally through the horn plates of a rigid engine frame beneath the spring bearings. The advantages gained by this were, first, true radiation of the axle to every curve, from the straight line down to one chain an-a-half radius; secondly, perfect guidance and prevention of irregular movement in the wheels; thirdly, facility in axle bearings and lubrications; fourthly, the use of larger wheels than could be obtained by the bogy system.

The writer proposed to build the engine with coupled driving wheels in the centre, and with radial wheels at the ends, eight wheels in all, and so, having ample support, to dispense with a separate tender. This was so novel a plan, departing from the customary bogy system, that it was not listened to, and bogies were continued.

The writer sent a drawing to Mr. Cross, the engineer of the St. Helen's, and about nine months after received a letter from that gentleman stating that after having found it necessary to use larger engines for his increasing traffic, he had studied the whole question carefully as to the best principle of radiation for his sharp curves;

and having come to the conclusion that the plan of the writer was the simplest, safest, and most effective, as well as the least costly, he had constructed a model and verified it experimentally, after which he put in hand a full sized engine. (A large sized model frame of this may be seen on the table.)

After working for some time on the St. Helen's, both for passengers, goods, and coal, and perfectly establishing the soundness of the principle, this engine, called the "White Raven," was brought to London for experiment, and examined and experimented on by a large number of railway engineers, whose judgment confirmed the truth of the principle of structure.

It was at first supposed that the free movement of the wheels would tend to make the engine unsteady on straight lines at high speeds, inasmuch as front wheels, fixed laterally in the horn plates were supposed to exercise a steadying and governing power. But the contrary proved to be the fact. Another engine, altered from the rigid system to the radial, was found to run much steadier after the alteration, after acquiring the facility for rounding sharp curves. In truth the unsteadiness of all engines, apart from bad construction, arises from the fact that the wheels, fixed to the frame and seeking the path of least friction over uneven rails, force the frames to partake of their irregular movement; and, as might be expected, the inertia of the engine frame keeps it steady enough when the wheels are left free to pursue their own courses unshackled.

This novel arrangement comes at a convenient time, as the extension of railways through towns and mountainous countries is now the prevalent thought. But even for what are called straight lines, their extension into and through towns, and new station accommodation, renders it very important to have engines working round very sharp curves, and either end foremost. The great cost of land and the removal of buildings in approaches where only straight lines of very large curves can be used adds very materially to the cost of construction. But there is another question, quite as important. It is well known that the rapid wear of the rails of railways is very largely owing to the weight of the engines, apart from the train, and in the engines the destruction by rail crushing is increased in proportion to the weight on the driving wheels. Some engines have only one pair of driving wheels, as they involve less impedimental friction at high speeds. Some have two pairs coupled together, and some three pairs. Inasmuch as the engine draws the load by reason of its own weight on the wheels giving adhesion, it follows of course that a heavy train needs more weight on the driving wheels than a light one. When a single pair of drivers are used the load sometimes approaches to fourteen or fifteen tons, and this crushes both rails and tires. If, however, the load can be distributed over more wheels, this destruction may be avoided. Twenty tons on four wheels is much less damaging than fourteen tons on two wheels. For this reason our continental neighbors have been aiming at two things combined—to obtain the adhesion of many wheels with the facility of passing round sharp curves.

The ordinary method of coupling wheels by side rods does not admit of this, and the writer has resorted to another method, illustrated by the model on the table, which, as regards its eight lower wheels, is precisely similar to the St. Helen's engine, the "White Raven." But in addition to this, it has four other wheels, two of which are placed at each end resting between the central driving wheel and the end radial wheel on their peripheries, pressing downwards with any amount of weight needed to induce adhesion. In fact the whole weight of the engine and frame may be supported by the upper wheels if needed. But practically a comparatively small weight is needed, as the wheels do not merely rest on one another, as is the case with the wheels on rails, but have also a wedging action, which may, if permitted, produce an intense pressure. All the wheels have also spring tires, which ensures elastic contact and fit, without blows. It will be seen that when the driving wheels are put in motion, they communicate that motion by friction to the upper wheels, which in turn communicate the motion to the radial wheels, and continue to do so when the radial wheels are on curves, the effect being that the axles of the upper wheels depart from the horizontal line, dipping to right or left according to the lengthening or shortening of the distance between the lower wheels on curves. And the adhesion is perfect, because the load on the upper wheels forces down the lower wheels to a perfect pressure on the rails at either end of the engine. Thus there are eight drivers which may be equally loaded and the whole weight of the engine is available for adhesion. And in reversing, for the purpose of retardation, the whole of the wheels are available. To make the machine complete, brakes are applied between the driving wheels, arranged to act both against the wheels and rails by small steam cylinders, so that the retardation of the engine is within the control of the driver by simply turning his regulator and steam cocks, without needing the muscular force of his fireman, laboring at a screw with slow movement. It will be seen that this engine will run on S curves as easily as on regular curves.

Of course the steam power of an engine should be in proportion to the adhesion. Practically it is far in excess of the adhesion, inasmuch as sand is commonly used to prevent the slip of the wheels; and this though useful to the engine, is a serious disadvantage in increasing the resistance of the train. This seems certainly the case on the Great Northern, where it is found advantageous to make the tender wheels drivers, as well as those of the engine, with the same boiler power.

In the early days of railways the difficulty of adhesion between a smooth tire and smooth rails was considered to be great, before it was tried. But in those days the trains were light, and the increase in weight has again drawn attention to the desirability of increasing the adhesion. Racks on the rails and wheels might no doubt be used, as they have been, and as they are still in some collieries; but this can only be for very slow movement. Yet there is a mode of increasing adhesion not yet resorted to, but which will probably be resorted to, where the whole difficulty of mounting steep ascents, such as one in twelve, or 440 feet to the mile, shall occur on any sharp curves. It is to convert the rounded flanges of the wheel tires into two flats at an angle of 45 degrees, and enlarging them to take a corresponding groove formed in the surface of the rail. The driving wheels of the engine only are to be fitted to these grooves, and the ordinary flanges of the train wheels can easily pass, being of smaller size. It may be remarked, that it would not be easy to lay rails accurately enough for this, and especially on curves, but compensation can be easily provided by the use of spring tires sliding laterally on the wheels, and there is no reason why the eight coupled engine before described should not work perfectly well in this mode, on sharp curves and stiff gradients. The pair of wheels on the table illustrate this principle of spring tires with angle flanges working in V grooves. The diagram on the wall illustrates this.

Thus with radial axle, spring tires, angle flanges, and elastic permanent way, several difficulties are got over. The blow and sledge movement is removed from between wheel and rail, as well as the grinding action against the flanges, and the adhesion is ensured, while the permanent way is rendered really permanent.

It may be objected to that the angular flanges will tend to wear away both tires and rails. This is quite true, but if we want to do hard work we must pay for it in some shape or other. The only question is, is it worth doing, and if so, what is the least costly method as well as the most effective and simple. We know that we can drive machinery by friction pulleys, and there is no mechanical reason why we should not drive railway trains. And these tires can be removed and replaced with perfect facility without needing workshops.

But it is not merely the question of engines that we have to deal with. It is that of carriages and wagons also. These vehicles have been kept short, and their wheels disadvantageously near together, chiefly on account of the difficulty of curves. This system needs remodeling, but there are so many considerations that it must be deferred to another paper.

Discussion.—Mr. Rochussen fully agreed with the principle laid down, that in order to neutralize as much as possible the wear and tear of materials by friction, they should have elasticity, and that elasticity might easily be promoted by the improvement of materials themselves as pointed out in the paper. There was no doubt the introduction of steel into the manufacture of rails tended to add to the durability of the rails as well as to introduce the element of elasticity to a large extent. The Bessemer process enabled them to produce steel rails at a comparatively low cost; at the same time it had not superseded the other description of steel rail which was largely used on the Continent, viz: the puddled steel rail, by which the tendency to split, spoken of in the paper as occurring in the common iron rail, was obviated and the advantage of puddled steel was, that it welded well with iron. Thus they had a flat-bottomed or Vignolles rail, which was still used to a large extent on the Continent, consisting of a head and web of puddled steel, and an iron base. The welding of the steel and iron was complete, and while this combination gave a harder surface to the tread of the metal, the elasticity of the iron was retained. He had seen the advantages of that combination of material at the Hamm station of the Cologne-Minden railway, the traffic of which was equal to that of Cresse, where steel headed rails with iron web and base had been in use for ten years and showed no signs of wear. Bessemer steel would not weld well with iron, and therefore it was best adapted for the double-headed rail. As far as the elasticity of rolling stock was concerned, he greatly admired the plan of Mr. Adams, of introducing an elastic material into the tire of the wheel. But he (Mr. Rochussen) would remark, that the combined steel and iron he had spoken of in rails, was also applied to wheels, and offered all the advantages of elasticity contended for. Both wrought and cast iron disks in straight section were objectionable, whilst in a corrugated section the wheels have a power of contraction which counteracted the force of the blows; and, on the other hand, they had but little vibration laterally. The great advantage of the disk wheel was that it did not raise the dust as the spoke wheel did, and obviated the great atmospheric resistance which the fan-like motion of the spokes created. With regard to the system advocated by Mr. Adams, he would ask how it could be ascertained when the piece of *lignum vitæ* or other wood inserted between the wheel and the tire showed signs of decay, as it was completely hidden from view, and there were no visible means of knowing when it became in an unsound state. While on the subject of disk wheels, he would remark that wrought iron disk wheels, which were much in use on the Continent, were working their way gradually in this country. In the Exhibition of 1862 a manufacturer with whom he was connected, showed some driving wheels on the disk system, which weighed 2½ tons each, made of cast steel, that material being considered better than wrought iron; but it appeared that wheels of that description were greatly affected by severe changes of the temperature of the atmosphere, and in one night no fewer than nineteen of those wheels cracked, while there was no instance of wrought iron disk wheels having given way under atmospheric influences. The iron was forged from the bloom, with a hammer weighing five tons, and the cast steel tire was batted on to the T-piece of the disk, or a puddled steel tire was used and welded to the disk, and as the steel surface of the tire wore off, it could simply be turned down, and another steel tire slipped over it, but hitherto no instance of the wearing out of such a wheel had occurred. The axles are not keyed in, but pressed into the wrought iron nave with hydraulic power.

Mr. Dennet felt much indebted to Mr. Adams for the paper he had read, but he wished that gentleman had gone a step further, and had given them a little more information as to the means of avoiding many of the risks of railway traveling. With regard to wear and tear of the line and plant, it was a question of great importance, in which the shareholders of railways were very much interested. There was an invention connected with this part of the subject to which he would call attention. The inventor of it, Mr. Jowett, he had hoped would have been there that evening to explain it, but his sudden and unexpected death within the last four days had deprived them of the valuable information which he would have furnished. The invention alluded to was a form of fish-joint, models of which were on the table for the inspection of the meeting. For this invention he had received but £12 10s., whilst it had been disposed of to a company for £21,000 and they had realized from it £80,000. Mr. Dennet then called attention to the specimen of rails, sleepers, plates, and a new fish-joint, all of which were the invention of Mr. Jowett, and he pointed out the advantages of this "rail" and mode of setting as obviating two or three difficulties in railway traveling. The ordinary rail was from five to seven inches in height, and being fixed in iron chairs on the top of the sleepers, there was a vibratory motion, which gave that zigzag movement so unpleasantly experienced by railway travelers. In the model before the meeting the rail was set in a groove to half its depth of the sleeper; there was a slot or hole cut in the rail, through which a wrought iron wedge or plate was inserted eight or nine inches in length by four or five inches in width and one inch thick, which plate was fastened to the sleepers by bolts or spikes. By this plan there was not only a saving of wear and tear of the rail but an economy in first cost. It could be adapted to rails of any material and of any shape. It could be applied to a light but serviceable rail, it dispensed with the wooden keys and chairs and lessened the number of sleepers by two in the length of rail. The saving in the cost of laying rails was equal to £300 per mile. In India it would be found that the economy of this plan was equal to £400 per mile, or £40,000 in 100 miles, while in this country the saving would be about £28,000 in the same length of line. Mr. Dennet added that this plan had been tested during seven months on a short length of the South-Western Railway, where it could be seen by those interested in the subject.—Mr. Dennet also exhibited a form of fish-joint which he considered novel, and highly advantageous and practical.

Mr. Zerah Colburn, on being appealed to by the Chairman, said his observations had been confined mostly to lines in America, and, as far as his experience went, it bore out the soundness of the principles brought forward by Mr. Adams. The American lines were, for the most part, imperfectly constructed, partly from the inferior quality of the earthwork and want of ballast, and to a great extent from the bad form of rail—the common contractors rail, with a flat foot, but of bad shape and bad quality of iron. Mr. Colburn explained the form of rail generally used, showing how the contractors form of rail, which could readily be fished, had, owing to the bad quality of the iron, in order to gain strength been altered into a form which did not admit of fishing. Nevertheless it was the fact that American carriages traveled over these lines as smartly as first class carriages on the superior lines of this country. This he thought was mainly due to the use of the bogy, the great length of the carriages, and the manner in which they are hung. The bogy had the advantage of going round curves easily, and the mode of attaching the carriages to it distributed the weight more uniformly; if they met with an obstruction the shock was not imparted to the carriage. The arrangement for allowing the carriage to swing freely on the body of the bogy, as adopted in America, had been introduced on the Metropolitan Railway, where it would be noticed that the carriages have a peculiarly easy motion. Mr. Adams had spoken of the bogy as having been originally invented in America, but he believed it was first introduced by Mr. Chapman, of Newcastle, in the year 1812, and was first used there. It was taken up in America at an early period, and had continued in general use ever since. It was the opinion of some locomotive engineers in this country that the use of the bogy to engines and tenders was not so safe as placing the wheels in the ordinary manner. He thought that was a mistaken opinion. He had designed some rolling stock for one of the Brazilian lines, and in opposition to his advice the bogy was dispensed with; but experience in the working of heavy gradients and sharp curves led to the ultimate adoption of the bogy. With regard to elastic wheels, something on the principle described by Mr. Adams had been used with success in the States of America, but not of the form which that gentleman had described.

Mr. Dennet inquired whether Mr. Colburn could give any information as to the description of wheel in use on the Massachusetts line, which he had been informed had resulted in great economy of wear and tear.

Mr. Colburn was not acquainted with the kind of wheel used on the line mentioned. He apprehended it would be something similar to those on the South-Eastern line in this country, viz: segments of wood put together. He would, however, add that one objection to the bogy was the necessity it entailed of using wheels of small diameter. A larger diameter than three feet was never used. As a rule the carriage wheels were 2 ft. 9 ins., and the engine wheels 2 ft. 6 ins., and for goods engines only 22 inches. The plan of Mr. Adams enabled a much larger wheel to be used, and this was, in his opinion, a decided advantage.

The Chairman said there was no doubt Mr. Adams had introduced a very important subject for discussion that evening, advocating, as he did, a radical change in the construction of our railways and the rolling stock. On the first introduction of railways he had no doubt it was in the recollection of many that a very rigid road was made. In the first instance the rails were laid on chairs fixed into stone blocks, and one line, he believed in the north of England, they actually built brick walls, on which they laid the rails. All those arrangements caused the rails to be knocked to pieces very soon, and engineers then resorted to wooden sleepers laid upon ballast. The Great Western Railway was, in the first instance, constructed by Mr. Brunel by laying longitudinal sleepers on piles driven a considerable depth in the ground, but at the points where these piles supported the longitudinal bearings great injury resulted. These piles were consequently all removed. The system was changed, and the sleepers were laid simply upon the ballast. This, therefore, appeared to be the great object at which railway engineers were aiming in order to avoid or mitigate the shocks produced by railway trains. He therefore thought no one would be disposed to object to a trial of the plan proposed by Mr. Adams. To him (the chairman) it seemed a most reasonable plan; but, of course, in railway experience it would not be prudent to express any very decided opinion upon a new principle of construction until it had been tried for a considerable time. The arrangement which Mr. Adams proposed for making the tires revolve on the wheels was certainly new. It had been tried, and was a great advantage. It had long been sought by railway engineers to make the wheels revolve upon the axles. The principle of Mr. Adams was very much to the same effect. It made the periphery of the wheel the point at which the revolution took place instead of on the axle. With respect to the fish-joint which Mr. Dennet had claimed for Mr. Jowett, he believed there were a great many persons who laid claim to its invention. He knew that Mr. Adams put in claims for that many years ago, and he knew many others who also laid claim to a mode of fishing rails. He had no doubt that by Mr. Jowett's plan a certain amount of elasticity would be obtained, but Mr. Dennet had not stated whether the sleepers themselves would not be weakened by that arrangement.

Mr. Dennet replied—Not at all; quite the reverse. He would add that he did not claim for Mr. Jowett the invention of the fish-joint, but that particular form of fish-joint to which he had referred. It was different from that of Mr. Adams's, the ingenuity of which he did not wish to detract from.

The Chairman said he remembered a system of fixing the rails into timber as long as twelve years ago—not exactly like that shown to-night, but very similar to it, which was tried on the South-Eastern line near London-bridge.

Mr. Dennet said that Jowett's plan of fixing the rail in the wood was different from that alluded to by the Chairman, and was quite new. In the plan referred to by the Chairman the metal was embodied in the wood.

The Chairman then proceeded to say that these various proposals of Mr. Adams undoubtedly tended to diminish a very great amount of the friction which took place in railway trains: and any diminution of those forces would practically be a diminution of the cost of working and an increase of dividends to the shareholders; and he trusted it would eventually lead to a diminution of the fares charged to the public. In that respect these matters were of the greatest public importance, and he was sure the meeting would readily accord their thanks to Mr. Adams for his very able paper.

The vote of thanks having been passed,

Mr. Adams said he took no credit to himself for the invention of the fish-joint, for five hundred different people, setting down to patch a rail as he did in the first instance, would probably have come to the same conclusion, only he happened to be the first to place such an invention on record. He never considered the fish as used was good, and he set himself to devise what he thought was a good fish on the plan he had laid before them. With regard to wheels, he did not enter into the question of which was the best structure, but merely alluded to the disk wheel as a form to which he wished the elastic tires to be applied; but the spring tire was applicable to all kinds of wheels, whether on common roads or on rails, and the section on the wall showed a mode of applying spring tires to road locomotives. The subject was too extensive to be dealt with in one paper, and he would deal with other branches in the paper which was to follow. He wished, however, to impress upon the meeting that it was perfectly practicable to make engines to go round curves of a radius of $1\frac{1}{2}$ chain, and he claimed a plan of distributing the weight upon all the wheels of an engine instead of principally upon the driving wheels. As to the mode of fixing the rails in the sleepers, there had been several plans proposed of cutting the sleepers, but they were all open to the objection that by cutting into the material of its sleeper its strength was impaired. If a sleeper with the ordinary chair required five inches in depth, then when it was cut away to the depth of three inches, it ought to be eight inches in depth in order to make up for the part cut away.

The Construction, Traction, Retardation, Safety, and Police of Railway Trains. By W. BRIDGES ADAMS.

From the Journal of the Society of Arts, No. 629.

(Continued from page 153.)

Discussion.—Mr. Dyer said they must all feel much indebted to Mr. Adams for his paper, which contained many valuable practical suggestions, but it did not embrace the popular view of the safety of railway trains by night and by day. The popular view was how the safety of passengers could best be secured, and how the casualties of railway traveling could be diminished. With this in view he would call attention to a few statistics taken from the annual reports of the Board of Trade, which showed that there was great loss of life annually throughout the kingdom from railway casualties. Those statistics had been tabulated only since the year 1861, in which year he found that there were 284 persons killed and 883 injured; in 1862 there were 216 killed and 600 injured; and in 1863 there were 184 killed and 470 injured. These figures showed a large amount of loss of life and injury to persons by railway traveling, making a total for the three years of no less than 2637. The question in which the public were interested was, could this loss of life and injury to person be reduced? and in this they were more interested than in the mechanical management or construction of a railway. A great number of lives, he believed might be saved, in cases of collision, by a contrivance (a model of which he had placed on the table,) and which, he said, would prevent the upsetting of carriages in case of collision. The loss of life occurred, in a great measure, from the upsetting of carriages on the road. If the carriages could be maintained in their proper position, the passengers would seldom suffer more than a violent shaking, but, immediately a collision occurred the upsetting of the carriages ensued, and loss of life and injury to person, to a great extent, was the result. He considered the present buffer arrangements of trains extremely faulty, inasmuch as their line of action was too low, and gave a leverage or pressure, which in case of collision lifted the carriage over. He held that there ought to be what he termed a square pressure from end to end of the train, which would enable the carriages to sustain the pressure without being upset; in other words, the carriage could be pressed to the extent of the crushing power before it gave way. The arrangement he suggested consisted of a top and bottom line of buffers, which rendered a train like a continuous carriage in point of resistance to pressure from end to end. If the train could be formed of one continuous carriage, upsetting would be impossible, for, however violent the concussion might be, it would be impossible to upset the carriage. The arrangement of buffers he had suggested would practically make the train into a single carriage. Another question was the frequent loss of life that occurred at station platforms, from persons getting in or out of carriages while in motion. He submitted that all the platforms should be built up to the level of the flooring of the carriages, and that a dangerous space between the platform and the carriages ought not to exist. There was a great want of uniformity in the height of railway platforms. He found at Charing-cross station the height of the platform was three feet, while the average height of the flooring of the carriages was about four feet from the rails; consequently, there was an ascent of twelve inches to the carriage. At London-bridge station it was about the same. On the Brighton line, at London-bridge, the platform was only twenty-four inches in height, which gave an ascent of two feet to the carriages, with a space of eighteen inches between the edge of the platform and the carriages, and this he held was dangerous in the extreme. However thoughtless or stupid the public might be, they found that casualties from falling between the edge of the platform and the carriages frequently occurred to the servants of the companies, who might be supposed to know the danger that existed. Mr. Dyer instanced the casualties that had lately occurred from this cause at the Erith Station, when the platforms were crowded with persons returning from the scene of the recent explosion there. He also quoted from the Board of Trade returns other accidents which he said were merely recorded as "passenger killed from want of caution," &c. He thought the Government ought to instruct the inspectors to inquire into and report the conditions and particulars under which the occurrence took place, but this was not done, except in the more serious cases of accidents. He thought many of the present dangerous arrangements on railways ought not to be allowed to exist, and that it was the duty of the Government, upon the neglect of the Companies themselves to do so, to enforce the necessary precautions to ensure the public safety.

Captain Humby could not see the practicability of the arrangement of buffers that had been suggested, to carry out which would involve the necessity of building excessively heavy carriages, whereas it was considered essential, both in regard to speed and comfort in traveling to build them as light as possible. He thought if such a system had come under the notice of Mr. Adams in a way that he could entertain he would have noticed it in his paper, and given his opinion upon it.

Mr. S. Teulon said the last speaker but one had suggested that railway carriages should be provided with two sets of buffers. He would appeal to gentlemen who had any knowledge of mechanics and of the laws of bodies in motion, whether it was not undisputed that the best point at which to stop a body in motion was not as near as possible to its centre of gravity. In the case of an engine with the boiler filled with water, and perhaps carrying a tank on the same frame, he submitted that the line of the centre of gravity was not very far from where the buffers were ordinarily placed. At one time the practice obtained of stopping trains on sidings by the very ready but, as it proved to be, very dangerous method of turning up the ends of the rails. The consequence of this arrangement was, that as the centre of gravity was above the wheels, they, coming in contact with the bent up iron, had a tendency to be thrown out of their places. The remedy for this was found in putting up an earth bank, against which the buffers impinged, and he could state, from his experience on a very large railway, that since that plan had been adopted the injury to the wheels and axles had been largely diminished. In the plan now suggested what would be the consequence of any thing happening to the lower buffers? If the top buffers took the strain, it would push the roof off the carriage, which, he apprehended, would be very inconvenient to the passengers inside it. With regard to the complaint that the platforms were not placed at a uniform convenient height, it must be remembered that railways were not the system of a day. They had gradually grown up, and improvements had succeeded from time to time. In making a new station, such as the Charing-cross, the directors had adopted a higher platform. The Brighton station was built many years ago, but he had no doubt, when it became necessary to make new stations, the directors of that company would follow the example of their neighbors, the South-Eastern. While speaking of the Brighton Railway, he would notice a passage in Mr. Adams's paper, in which he referred to a subject which had excited a great deal of public discussion, viz: the alleged injury to the health of persons constantly traveling by railway. The best answer to that allegation was the fact that, taking the statistics of the Brighton Railway he found a very large increase from year to year of the class of passengers daily traveling to and from Brighton and intermediate stations as season-ticket holders. The report which was distributed among the shareholders of the South-Eastern Railway Company it the early part of this year contained a table, which showed that while in 1855 the season-tickets brought in near £21,000, the amount had gone on increasing year by year, with but one exception, until up to the present year it reached the sum of £34,693. He at one time, as a traveler by railway and road 72 miles, four or five days in a week, fell into the notion that he was being seriously injured by his railway traveling; but he must own now, having continued that injurious practice for upwards of ten years, he had the satisfaction of enjoying much better health than ten years ago. It was fair he should state the result of his own experience. He attributed much of the injury which some passengers suffered to this cause, viz: the short time that persons gave themselves to reach the station, which led to their arriving and entering the carriages in a flurried and heated state, unfit for traveling, especially in cold weather. They sat in drafts caused by the carriage moving rapidly through the air, and the caloric of the body was rapidly drawn from the feet, and the proper circulation of the blood interrupted. He turned from this question to the practical matters treated of in the paper. With many of the points advocated by Mr. Adams he entirely agreed. He agreed that a great deal of the mitigated wear and tear of railways and rolling stock was to be attributed to the better form of construction both of the line and the working plant. He had taken a little trouble in this matter since the last meeting, because he held it was of great advantage to discuss these subjects with a number of gentlemen more or less conversant with it, and although they might not agree on all the opinions expressed, they were in all cases the better for exchanging ideas with each other. In the year ending 1855, on a railway on which 2272 carriages were employed, it was necessary to "turn up" from wear 1884 pairs of wheels. The actual result was ·6726 as the proportion of wheels turned up in 1855, whereas for the year ending July last, the number of vehicles having been materially increased, and increased in size as well, the capacity of the wagons being increased from four and five tons to eight tons, they still found this gratifying fact, that the ·6796 in 1855 was reduced in 1864 to ·6533; and it was an equally gratifying fact that the quality of the tires—a matter on which Mr. Adams properly laid great stress—had very much improved, especially the Staffordshire tires. He found, on a comparison between the wheels used on two of the large metropolitan lines, that while in the four years ending 1863, when a great many Low Moor tires were used on the one line, the result was a loss of ·60945, on a neighboring line with Staffordshire tires it was ·60990, being a mere difference of $\frac{4}{10\cdot000}$, and showed very favorably for the Staffordshire iron, which, ten years ago, they hardly dare use, as the quality did not near come up to that of Low Moor. With regard to wheels, the railway he was connected with (South-Eastern), gradually, during the last fourteen years, ceased to have perfectly solid iron wheels; they employed wood placed endways above a plate inserted for the centre of the wheel, and built up to form a wooden disk on which the tire was put by hydraulic pressure; they had also done this, and done it very successfully, viz: placed a rim of wood between the iron wheel and the tire. He should state that the former plan was patented by Mr. Mansell, the carriage superintendent of the South-Eastern. As the tires had become worn, they had cut out of hard wood a segment of an inch or an inch and a half, and placed them between the inside of the tire and the iron forming the old wheel. These plans had answered so well, that whilst during the last severe winter, the tires of 150 pairs of wheels, some on iron, had elongated, where this hard wood had been placed between the tire and the wood of the disk, there was no wheel amiss, a very important matter in times of severe weather. The elongation of tires in winter time had been a very vexed question, but he thought a little consideration would bring them to this conclusion. The road in severe weather, especially if the frost had been preceded by wet, was in its most rigid state. Then the inner portion of the wheel, when of iron, was in effect the same as if the tire was placed between rollers, and consequently it elongated the tire. With reference to the model of an elastic road shown by Mr. Adams, he imagined that was another move in the right direction, and that plan had been adopted on one of the lines running from Manchester. The chairs were placed between the wheels, as in that model, and he stated this on the authority of Mr. Ashcroft.

Mr. Adams—If the plan was good why did not Mr. Ashcroft employ it on his own lines?

Mr. Teulon said it must be well known to Mr. Adams that a framed longitudinal road was formerly employed on the viaduct portion of the Brighton line, and was one of the best parts of the line; but owing to the great number of trains, when it was taken up it was impossible to put down another road like it. It was, however, in use some ten or twelve years with success. With regard to the spring tire wheels which Mr. Adams had shown, he (Mr. Teulon) thought that in ascending inclines difficulty would be found, inasmuch as the wheels would slip in the tire for want of sufficient friction.

Mr. Adams—The objection could only apply to the driving wheels of engines; as regarded other wheels, facility of slip was a positive advantage. As regarded driving wheels positive experiment, which was worth more than any theory, had demonstrated that even when the tires, as stated in the paper, were so loose that they could be moved round by hand (with the weight lifted), they drew their load perfectly well. Mr. Adams would go further, and say that loose tires, even without springs, would act in the same way, although of course disadvantageously for want of the elastic interception of blows, and the equalizing movement of the tire on its basis of contact with the rail.

Mr. Teulon added that Mr. Adams had stated very correctly that all changes with regard to railway plant, especially with heavy and powerful bodies like engines, must be made with great caution, and therefore he was content to wait on this point till he saw more of the results. In conclusion he would say a word on the subject of the fish joint. He saw by Mr. Adams's previous paper that he did not call in question the fish-joint at present in use, but he said he had got something better. He (Mr. Teulon) thought the public was very much indebted to Mr. Adams for his original fish-joint, and he hoped that gentleman had reaped some of the benefits of that invention. [Mr. Adams—Not a sixpence.] It was a good joint if the fish were properly made, and was one of the best things that had been introduced on railways for a long time. He would not say Mr. Adams might not have improved upon it, but the original joint had been a great advantage to all railways that used it.

Mr. Adams, in reply to the observations that had been made, said the model of the suggested application of double sets of buffers was simply a supplementary mode of attaining what he himself had advocated in the paper, viz : the long carriage. In the early days of railways a single buffer was used in the centre, but it was abandoned for the two side buffers. He did not agree with Mr. Teulon that it was a bad plan to put buffers in the position in which they were shown in the model, because it was notorious that short carriages would ride upon one another's backs. No sooner did they come into collision than, with four tons of buffer springs pressing, the first thing they did was to mount upwards on each other's backs, as they could not move downwards or sideways. That was well known from experience. He did not think that two sets of buffer springs, one above and one below, were desirable, but he thought it would be an advantage to apply cushioned blocks to the upper corners of the body, flush with the buffer heads when drawn home, to lessen the risk of the tilting upwards. With regard to the question of health, he could not fight against statistics ; but in his paper he had alluded to what he understood was the fact, not that season tickets originally taken by gentlemen wishing to travel morning and evening to and from Brighton had been discontinued, but that very few persons could keep up the daily practice ; and though the season tickets might have increased in amount *non constat* that all their owners traveled with them morning and night.

Mr. Teulon said his inquiry had been especially directed to that point, and there were persons traveling backwards and forwards continuously.

Mr. Adams was glad to find they had such quality of muscle in England, but one engineer had told him the practice did not suit him. And it was notorious that the faculty discouraged their delicate patients from the use of the railway. With regard to the wheels which Mr. Teulon had alluded to, before that gentleman had gone far in his remarks on that subject, he (Mr. Adams) was prepared with a reason why the wheels on the South-Eastern Railways had lasted longer. It was solely due to the fact that they were wheels with solid wooden disks, which to a certain extent rendered the wheels true circles, and also removed the inner anvil from the tires. They could not hammer the tire on the surface of the wood as they could on an iron surface, just as the shoemaker in hammering his sole leather could not do it on his thigh as he could on a solid lapstone. As to wooden wheels, nobody knew more about them than he did. He was at one time a manufacturer of carriages and engines, and had turned out a great many of them. There came to him an order from the South-Eastern Company for a number of very long carriages. Those carriages were notoriously the steadiest carriages that ever ran, but they did not answer in one respect, as he had not in them a radial movement of the axles, and the flanges cut against the rails. When the order for them was given, it was specified that the wheels were to be constructed on Mr. Mansell's patent. That patent was not for wood wheels, but consisted in applying, in an ingeneous manner, a pair of angle iron rings which keyed laterally into the grooves of the tire, and held to the wheel by cross-bolts through the wood, piercing through the head of the tire. In making a wheel the worst thing they could do was to make a hole through the tire, because it deprived it of a portion of its strength—probably one-third. Another thing was, when the tire got loose on the wheel it indicated danger, which arose in this way—Where the tire was stretched by the process of rolling over the rails, the wheel being held down in eight points, it could not stretch where it was held, but became polygonal in stretching out between them, and the wheel in other parts became a sledge hammer, and in frosty weather, the rivets got broken out. The original wheels of Mr. Mansell were composed not of a disk of wood, but of a series of screw spokes, the outside secured in the felly, and the inside in the nave of the wheel. On looking at that plan, he declined to make such wheels. He was asked how he could do it. He replied, make them solid disks with a series of radial timbers. He was told that was the patent of another superintendent, but he doubted the fact, as it had been done by Mr. Dricks many years before. He (Mr. Adams) had machinery made to cut the timber for those wheels, and they were the first that were thus made for the South-Eastern line. He was then putting on Park-gate tires, said to be of brittle iron, but he found it perfectly hard, and of good quality. While these wheels were in course of of manufacture, an accident occurred on the Midland Railway by the breaking of a tire, which cut through the bottom of the carriage, and nearly killed the railway king, Mr. Hudson. Inquiry was immediately made of the officials whose tire was that had broken? and on being informed it was Park-gate, he issued orders that no more of those tires should be used on any railway of which he had the command. Upon this he (Mr. Adams) was asked if he intended continuing to use the Park-gate tires? He replied he did. He was told they would break, to which he replied he was putting them on the wooden disks by pressure, and by no subsequent pressure could there be sufficient tension put upon them to break them. He believed these wheels had never broken a tire. The greater duration of the South-Eastern wheels was, therefore, due to the action of the wood, which prevented the rails and chairs becoming anvils for the tires to act upon. In America Mr. Griggs had put his engine-tires on with wood between the tire and the wheel, and by that means, no doubt, had increased the duration of the tire very considerably; but in the case of a wooden wheel, if the tire got loose by any chance and began to move round, it would soon grind the wood wheel away. With regard to his plan of laying the rails elastically, a few years ago, Mr. Chubb, a director of the North-London Railway, complained to him of the destruction of the rails on that line. His reply to that gentleman was, that they did not lay them right, and he offered to give him a plan if he liked to use it. A few lengths were laid down on the North-London line with the ordinary rails and in other places. The rails did not touch the longitudinal timbers, and were supported, not by chairs, but by brackets. They had been down three years, but they exhibited no signs of destruction on the top, as was the ordinary result of the anvil action of the chairs and hard ballast. At the time he read a paper on this subject before the Institution of Civil Engineers, it was stated that that kind of road had been adopted before, but he was unable to find any trace of it, in any book or publication, or transactions. It was asserted that it had been done by Mr. Buck, who he admitted was a perfect judge of a good line. He inquired where it had been laid, and was informed on a viaduct; but it had not been renewed on the same plan, and no one knew anything about it except those who laid it down. Mr. Teulon said he got his information from Mr. Ashcroft. Now the latter gentleman was a member of the Permanent Way Company, which had become possessed of his (Mr. Adams's) fish-joint. It was a company got together to secure all that was good in patents of every kind appertaining to the permanent way of railways. Mr. Ashcroft was, he believed, still a member of that company, and had a patent for a permanent way of his own, on which many heavy chairs were used, and it was only natural he should give the preference to his own plan. But that fact precluded either him or Mr. Teulon, who acted under his advice, from being unprejudiced judges of any clashing plan. He gathered from Mr. Teulon's remarks, that he wished, under his information from Mr. Ashcroft, to make it appear that he (Mr. Adams) was not original in his elactic system. But the truth he believed was, that Mr. Buck, a man in his own right, and not a copier, did use on a viaduct a system of interspacing his chairs between the rigid supports of the frames, to save the viaduct from damage. But in what was called the permanent way of railways, no such system was ever used. He (Mr. Adams) had embodied a known principle of nature to counteract the evil of hard ballast, more than once alluded to by the late Robert Stephenson, in discourses at the Institution of Civil Engineers. Mr. Buck was a man of clear perception, and he also took patents, but never took a patent for this elastic system, or ever mentioned it before scientific bodies. With regard to the framed longitudinal road on the Brighton line, alluded to by Mr. Teulon, it was laid with continuous bearing bridge rails on longitudinal timbers. The bridge rails deflected under the wheel and sunk into the timber to an inch or more in depth. An engineer of the South-Eastern line, when he first saw a rail removed asked, very innocently, "Why do you groove your rails into the sleepers?" thinking it had been done from the outset. This line was always harsh and rigid, and not one to be recommended. He (Mr. Adams) had devised a general system, and applied it equally to timber and metal sleepers, to prevent blows and breakage. With regard to the fish-joint, when the original joint was produced, he (Mr. Adams) had not intended it to be used in the way it was now used. It was produced as a parallel support to the rail ends between two chairs, six inches apart; afterwards, for the sake of cheapness, it was proposed to bolt it. The form which was good in the chairs as a parallel fish was not proper as now used. It was notorious that the fishes bent at the joint, and as they had only three inches depth between the two upper tables of the rails, they were not deep enough to supply an equivalent in strength to the depth of the rails. Another thing was, they were parallel, and, being parallel, they added more strength than was wanted at the end of the fish to the rail, and that caused a blow, and less strength than was wanted at the joint of the rail, and that caused another blow. He (Mr. Adams) had now devised another form of fish. It so happened that the Permanent Way Company had made what they called, an improvement in fishes, and probably a dozen patents for improved fishes had since been obtained, and it was certainly competent for him, who originated the fish, to make improvements upon it. He did not think the public were thereby endamaged, nor did he think either the public or Mr. Teulon would desire to dispute his right to make a profit of his further improvements, even though the first fish had yielded a miraculous draft of coin to its possessors. He had seen few fishes of a worse form than the last pattern on the South-Eastern line.

Mr. Davis wished to state that he had had some experience of the engine alluded to in the paper, as having been constructed for the St. Helen's Railway, and was present, in company with the most eminent engineers and locomotive manufacturers, at the trials made with it on the North-London line. When running on a straight line, at a speed of 68 or 70 miles an hour, he was very much struck with the beautiful motion of the axle boxes. Running at that high speed, an inequality of the rails would sometimes cause the engine to give a jump on one side, but it immediately righted itself in the most beautiful manner. After the experiments he examined the wheels, and he noticed that the flanges were not abraded, but the tire had formed a groove corresponding with the surface of the rail. Although the papers of Mr. Adams were very comprehensive, there was one subject which had not been touched on. It had been stated in the discussion that where one carriage ran off the line, if the couplings did not break, the other part of the train would be dragged to destruction. He had brought under his notice a very clever invention, by which the couplings of the carriages were so arranged that, taking into account the sharpest curves, the couplings, by a clever mechanical arrangement, immediately disconnected the carriage from the other part of the train, and saved it from destruction. He thought this contrivance should be more prominently brought before the notice of railway managers than it had yet been.

Mr. Adams said that on the St. Helen's engine they were all spring tires.

Mr. Davis replied in the affirmative, and added that he was much delighted with the sensible improvement in the non-vibration of the engine.

The Chairman had great pleasure in proposing a vote of thanks to Mr. Adams for his excellent paper. It was only to be expected that, looking at the scope of subjects embraced in this and the previous paper, difference of opinion on some points would arise. An objection had been taken this evening that Mr. Adams had not cared sufficiently for the public safety in railway traveling. Now if he understood aright the suggestions of Mr. Adams, they went very much in that direction, not only by diminishing the wear and tear of railways, but they had much to do with regard to the safety of the trains. He would not detain the meeting by entering into the fish controversy, but it illustrated the old adage that "there are as good fish in the sea as had come out of it." The first fish, and a good one, had been produced by Mr. Adams, and he was now ready to produce a better. Mention had been made of the safety of railway carriages, arising from their length and breadth, but no mention had been made of carriages having upper stories. For several years past that description of carriage had been worked on the Bombay and Baroda line, with much success and much safety, and so agreeable had it been found by the passengers, particularly the natives of India, that the company with which he was connected (Scinde, Punjaub, and Delhi,) had adopted the plan, and used it for a considerable period. He would state as a question of railway management, that they could convey in one of those carriages very nearly as many as they could in three ordinary carriages. Hitherto no accident had occurred, and the natives infinitely preferred the upper story. As one for many years connected with railways, he would express how gratifying it had been to him to have been present on this occasion, for he felt he had received a great deal of instruction, and it was very agreeable to him to hear that as they gained experience in railway construction the dangers of that mode of traveling were materially diminished.

The vote of thanks having been passed,

Mr. Adams acknowledged the compliment paid to him, and remarked that one element of safety in reference to those carriages on the Indian lines consisted in the gauge of 5 feet 6 inches, which allowed a wider base for the wheels of the carriages. With that gauge they could do a great deal more than with the national gauge of this country.

Proposed Great Iron Girder Bridge.

From the London Builder, No. 1140.

A great railway undertaking, resembling in character the Britannia, Saltash, and Victoria bridges, and surpassing even these in point of dimensions, is to be submitted for the sanction of Parliament in the ensuing Session. The North British, and Edinburgh, and Glasgow Railway Companies have given notice of a Bill empowering them to construct a great iron girder bridge across the Firth of Forth from near Blackness Castle, three miles above Queensferry, on the West Lothian coast, to Charleston, in Fifeshire. The plans of the bridge have been prepared by Mr. Thomas Bouch, C. E. The length of the proposed bridge is 3887 yards, or two miles 367 yards. It will be about 17 miles from Edinburgh, and 34 from Glasgow, and is intended to accommodate an express route from these cities to the north of Scotland, in connexion especially with what is known as the "east coast" route. Instead of a single span of 600 feet, with two side spans of 300 feet, which was the scheme of last year, it is proposed to make four spans of 500 feet each over the navigable channel, the spans diminishing to 200 feet and 100 feet on either side. The clear height of the bridge in the channel will be 125 feet at high water of spring tides, thus giving ample height beneath for the tallest vessels frequenting the ports of Grangemouth and Alloa. The frame of the girders over the widest spans will be about 70 feet giving a total visible elevation of 195 feet for the distance of nearly half a mile, the height diminishing at the ends of the bridge as the spans become reduced in width. Taking the submerged part of the work, the height will be 25 feet of foundation below the silt bottom, 50 feet of depth of water at ebb spring tides, and 18 feet of fluctutation of tides, making in all 285 feet in height of work to be executed. The middle piers will be of stone to the height of 10 feet above high water at spring tides, and the rest of the structure will be of malleable iron. The bridge will be built for a single line of rails, with a gradient in the south end of 1 in 134, and in the north end of 1 in 100, so as to give the necessary elevation in the middle. The dimensions of the Britannia Bridge may be stated by way of contrast:—Span, 460 feet; height, 104 feet; depth of tube, 30 feet. The cost of the bridge is estimated at between £ 500,000 and £ 600,000, but, on the other hand, the companies would save the capital cost of piers, breakwaters, and steamboats, and cost of working the ferries. In connexion with the Tay Bridge an unbroken express line would be provided between Edinburgh and Dundee, saving the inconvenience, uncertainty, and delay of the Burntisland and Tayport ferries.

For the Journal of the Franklin Institute.

Papers on Hydraulic Engineering. By Samuel McElroy, C. E.

No. 5.—*Fire Service and Hydrants.*

Continued from page 175.

Hydrant contingencies and defects.—The considerations of these points will be directed to the present forms, location, intervals, calibre, protection from frost, cases, and workmanship.

In the milder climate of the European cities, hydrant nozzles, encased at street grade and at street pavements are not as liable to obstruction from snow and ice, as in the more severe temperature of our Middle, Western, and Eastern States; and for this reason, mainly, they have not been adopted. The American hydrants, are placed along the curb lines of the sidewalk, and either "*flush*" with sidewalk grade, or with "*stand-pipe*" *heads*, the former being more common in the Eastern, and the latter in the Middle States, although the water administrations of the milder sections, object to the "flush" hydrant on account of winter weather. The more correct cause for their adoption, is to be attributed partly to the habit of following certain beaten paths, without much inquiry as to their alignment, and the desire to accede to the wishes and prejudices of the volunteer firemen, who exercise considerable rivalry in securing the first hydrants for their particular "machine," and have a special regard for those more readily found in the general race for precedence. In the hurly-burly of a fire-alarm and of arrivals on the ground, a fireman looks more picturesque seated on the hydrant which he has secured for his "machine," and can maintain his position better against the next comers, than over a flush case, without such salient points; beside this it takes the hose a shade easier, he thinks, and it certainly looks better in the engraving of his certificate or the elaborate art adornments of his engine and engine house.

On this point, the Jersey City report says;—

> "The kind of hydrant adopted here, and which has been used throughout the city, is the "flush hydrant," as it is called. Considerable fault has been found with them by the firemen, not in consequence of any failure to answer the purpose intended of them, but from a belief that they may cause some trouble and inconvenience, and perhaps also from a strong prejudice against them before they were put in operation. But, it is believed no trouble has yet been experienced with them, and that, if a fair trial is given they will prove satisfactory."

The firemen, in this case, made up their minds beforehand; but ten years actual experience has by no means vindicated their correctness; and the water-boards which adopt the logic of these firemen, as to flush cases, on the sidewalk, put down all their main-stop-cock boxes with flush heads, in the street centres or near the gutters, without a shadow of compunction over fixtures, which are of no less vital character. If in such cities as Boston, Charlestown, or Hartford, ice and snow are not serious obstructions to this particular form, they must be less so in cities of much milder temperature; if they are so located and cared for, as to be easily found; if less liable to freeze; if less costly and less liable to accident and less objectional to pedestrians, they have valuable qualities which should be discussed and admitted without prejudice, and particularly so, when the days of volunteer fire service are drawing to a close.

The matter of hydrant location, deserves greater care than it receives, and may be simplified by a general rule of position. If flush hydrants at street corners were invariably placed on the north-west and south-east corners, and on the west and east building ranges, at the curb line, they could be readily found; if those between the corners were placed near gas posts, or designated by house-marks, or placed midway for blocks over 200 and under 300 feet in length, and not over 200 feet apart in longer blocks, comparative strangers might readily find them, while policemen and habitues would never be at fault. As all hydrants are the subjects of special care and examination and as all sidewalks are required to be cleared of snow every morning, the flush cases need not be covered up by snow or ice so as to be at any time inaccessible. As they are shorter, warmer and cheaper and make their discharge with less friction, these advantages are in their favor. With low nozzle covers on stand-pipe heads, the plash from the gutter is apt to freeze them up, so as to require long wrenches to break the joint, in winter.

The relative *intervals* or distances between hydrants, have an important bearing on their usefulness in concentration of fire supply.

In London they are about 400 feet apart, while in Hamburg the intervals are 120 feet. In our own cities it is customary to call them

300 to 400 feet apart; in one report we are told that on the basis of 1853, Boston has a hydrant to every square of 212 feet, Philadelphia 270 feet, New York 323 feet, being 1137 hydrants to 51,000,000 sq. ft., 1015 to 76,000,000 sq. ft., and 1601 (1851) to 167,000,000 sq. ft. respectively; Baltimore and Albany were arranged on a basis of 300 feet square.

But if regard is paid to the average intervals, as determined by the number of hydrants connected with a given length of mains, we see that on their lines the intervals are much greater, being from 471 to 1530 feet.

The improvement suggested in action, requires in all denser localities, closer intervals. In every case there should be two hydrants at each street intersection; for blocks not exceeding two hundred feet this would answer without intermediates, and on long blocks the intervals, should not exceed two hundred feet; with two lengths of hose for the street corner, and two for each intermediate, two streams could be thrown into any building fronting on the street, from short hose lines, with great effect, and according to experience in other cities, in an average time of two minutes. Of the experience on this point, a few notes will suffice.

> "In five cases out of six, the hose is pushed into a water-plug and the water thrown upon a building on fire, for the average pressure in this town is 146 feet; by this means our fires are generally extinguished even before the heavy engine arrives at the spot."—*Oldham Water Works, England.*
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> "Throughout the whole length of the pipeage, are placed at intervals of 40 yds., fire plugs of 3 inches diameter in the clear. A jet can be applied in two minutes, all the fires which have occurred repeatedly, have been put out at once. If they had had to wait the usual time for engines and water, say 20 minutes or half an hour, these might all have led to extensive conflagrations."—*Hamburg Water Works.*
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> "At each fire station, reels of hose, each mounted on a light hand cart or barrow are kept; the bottom of the barrow forms convenient lockers for containing the stand-pipe, nozzle and tools, and the whole apparatus is so light that a man can run with it. On notice of a fire being received at a station, a couple of men set out immediately with one of these reels, others follow, and the remainder of the force busy themselves in turning out the engine. * * * And it may be a dozen jets are playing and the flames nearly extinguished before the engines have left the yard. * * * Serious fires are now seldom heard of, for before the flames can gain head, the jets can generally be played upon them and this is the only time there is a chance of subduing them."—*Liverpool Water Works.*
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> "Fires have occurred in Gorbals where they have been got under and extinguished before the arrival of the engines and their attendant hose. This is a matter of great importance in all large towns where so much property is annually destroyed by the ravages of fire."—*Glasgow Water Works.*

Improved *calibre* furnishes the third link in this chain of progress, the friction of the common form of hydrant tubes being a formidable obstacle to their proper action.

The calibre of hydrant tubes and valve openings have been noticed in the case at Philadelphia, and is not exceeded as a rule; the Brooklyn tubes are three inches in diameter with an inch valve rod, which practically brings them below the former example.

In remarks on relative calibre of service mains, experiments were noticed showing different effects on the same hydrant and base; at the same time experiments were made on hydrants.

In the case of the four inch main of 600 feet, from the 5 inch of 600 feet attached to the 9 inch main, the jet from one hydrant of $2\frac{1}{2}$ inch tube, in the clear, with 40 feet of hose and $\frac{7}{8}$ inch nozzle, rose 34 feet from the end of the service; with two hydrants and hose, the jets rose 23 feet; and this under a head of 120 feet on the connected lines of mains. Fixed near the 5 inch mains, one jet rose 40 feet and two, 31 feet.

The same attachments to the 7 inch main, gave for one hydrant in play a 50 feet jet, for two, 45 feet, for three, 40 feet, for four, 35 feet, for five, 30 feet, and for six, 27 feet; with one hydrant open, and 160 feet of hose, in place of 40, the jet rose 40 feet.

On the 9 inch main, one hydrant jet rose 60 feet, two, about the same height, four, 45 feet, and six, 40 feet.

We have here the effect of different lengths of hose, the jet of 50 feet, with 40 feet of hose, being reduced to 40 feet, with 160 feet, or 20 per cent.; we have also, the effect of additional hydrants, reducing the jet from 34 to 23 feet, from 50 to 27 feet, and from 60 to 40; the throw of 6 hydrants being $33\frac{1}{3}$ per cent. less than that of one on the 9 inch main, and 46 per cent. less on the 7 inch; we have also, a commentary on the severe loss by hydrant and hose friction, the greatest result-from 120 feet head, being 60 feet, or 50 per cent. less, and this with one hydrant on a large main, with a short length of hose.

The Detroit Report for 1862 gives the following notes on the time of discharge for 100 gallons of water, through pipes, attached to the hydrants, of three sizes:

Order of Position.	Reservoir Head.	Time with Pipe of					
		1 inch.		5/8 inch.		1/4 inch.	
		min.	sec.	min.	sec.	min.	sec.
15	33·1	1	19	2	32	14	4
14	34·6	1	32	2	46	14	28
8	36·0	1	32	2	51	14	20
7	39·0	1	27	2	38	13	4
16	42·0	4	31	5	55	28	14
12	43·5	1	58	3	41	18	51
9	48·7	1	53	3	17	17	6
6	49·7	1	35	3	4	14	54
4	49·8	1	40	2	59	13	42
3	49·9	1	24	2	25	12	43
13	50·9	1	16	2	11	10	40
10	51·0	1	45	3	9	16	0
11	53·1	1	45	3	9	16	0
5	67·5	1	16	2	22	12	26
2	72·7	1	14	2	9	10	37
1	74·3	0	47	1	43	8	54

This experiment cannot be rigidly analyzed, the results being affected by relative location in the general service of conditions of local draft. The Report says:

> It will be seen by the above tests that the hydrant at the corner of Sproat street and Woodward Avenue, (No. 7), discharged 100 gallons in about two-thirds the time the same quantity was discharged from the one at the corner of Fort and First streets, (No. 12), notwithstanding the theoretic head is greater at the latter point, showing the loss by friction and draft, the former one being located near the large supply main with but few water takers in the vicinity, and the latter a mile from it, in a district consuming a large quantity of water, supplied by pipes of small diameter."

But it furnishes an interesting comment on the relative friction of discharge tubes, in the quantities of water deliverable, and on the vigilance of one of the most zealous water administrations of the country. In the same report a complaint is made, that under a reservoir level of 77·5 feet;

> "The loss in the effective head of water in the central parts of this city, for want of sufficient capacity in the distribution service is from twenty to twenty-five feet."

At Wolverhampton, (England) with a head ranging from 200 to 100 feet, the ¾ inch hose jet rises 70 feet from the hydrant, and the hydrant power is stated at 50 per cent. greater than that of a 14 man-power engine. As compared with the London fire engines, one of 26 man power with two seven-inch barrels, produces a 50 feet jet.

At Brooklyn, the first hydrant opened for fire use, corner Schenck street and Myrtle Avenue, being about 120 feet below reservoir level, was obliged to be shut off to avoid washing Engine No. 10, which took its supply, after the fire with one length of hose it threw a stream 125 feet horizontally, with a 1¼ inch nozzle. At the water celebration the 7 inch jet of the City Hall fountain, rose within 11 feet of the reservoir head, more than 5 miles distant.

At Boston, the 6 inch jets on the Common, rose to 98 feet above tide, the reservoir flow line being 120.

Jet experiments by *Mariotte* with a circular orifice of 0·53-inch, gave the following results:

Head. feet.	Jet. feet.	Loss. feet.
37·7303	34·0886	3·6417
37·2382	33·1933	3·449
27·8220	25·8107	2·0113
26·0175	24·3443	1·6732
13·1564	12·7955	·3609
5·8728	5·7416	·1342
11·7128	11·2207	·5921

The last from *Bossut* for a vertical jet, became 11·3850 feet for a slightly inclined jet, illustrating the effect of the falling particles on the former, while all the results show the effect of friction at the orifice and atmospheric resistance. It is also laid down as a theoretical law, that "great jets rise higher than small ones; under the same head; having more mass, the resistance less promptly destroys their velocity, and they are less divided."

From these detached examples, several lessons may be learned. From the fact that 40 feet of hose, under certain conditions, threw 10 feet higher than 160, being a loss of ·083-foot per foot, the extravagant fiction of riveted hose is shown, as a good reason for reducing the feeding lengths for jets or engines, by increasing hydrants; while the loss of head in the London experiments is excessive, it furnishes a clear argument in favor of larger hydrants in calibre,—and especially in the American types, of their delivery from the objectionable feature of internal working gear, around which the water must force its way, with aggravated disturbance; the same lesson of effect through contracted tubes is taught emphatically by the Detroit experiments, in the differences of discharge.

On the other hand, we see it demonstrated practically, as we know it to be theoretically, that it is possible, by a judicious arrangement of conduits, to realize the effects of reservoir head, within a reasonable and moderate per centage of loss, and this in such a way as to demonstrate an actual superiority of power, over hand engines, although these have always the advantage of superior concentration and choice of position, for special work. This possibility, once admitted, answers all objections of cost, or custom, or novelty in our proposed application for primary fire service; if the proposed results are within reach, the end justifies all the means. It is said that increasing draft in time vitiates reservoir head, and it cannot, therefore, be relied upon; increased feed service will readily meet this defect, by means always applicable.

The fact that one hydrant tends to draw down another, illustrated in the London experiments, does not involve a valid objection to primary dependence on hydrants, carefully designed and located, since it will evidently require a smaller supply of water to do the smaller amount of fire service actually involved, but this fact is an important condemnation of the present system of delivery to the hydrants.

Various water works reports hint at the difficulty, which, in the words of the Cincinnati Report for 1847, "is now experienced when more than one engine is attached to a pipe, in robbing each other, and all the hydrants in the neighborhood."

The general adoption of steam fire engines, places this and the other effects named in a more imperative light, since they are so much superior to the hand engines in capacity and regularity of discharge.

On this point the following extracts are instructive.

"A change has been made in the hydrants, so as to adapt them to the steam fire engines, as was recommended last year, and all the hydrants set in future will be of the improved pattern. In connexion with the hydrants, additional precaution has been taken to insure an abundance of water in case of fire, by connecting the following fire reservoirs (street cisterns) with the main pipes."—*Boston Report for* 1861, *p.* 27.

"Great difficulty has been experienced in procuring an adequate supply of water for them (steam fire engines); this has in part been remedied by applying the suction of the engine immediately to the plug; while this gives a much better supply of water, the ram or concussion produced by the operation of the pump, loosens the joints of the plug or some of the connexions, and in one instance the main was burst; to remedy this defect and also to give a more copious supply of water, the department has constructed a fire plug of much larger dimensions than that now in use, and which has the addition of an air chamber to it, to receive the ram of the water. It is hoped by means of this that the steam fire engines can be worked without the city being put to the expense of constructing large cisterns to pump from."—*Philadelphia Report for* 1858, *p.* 30.

"The distribution service should never be laid in populous districts with pipes less than six inches diameter, except when short lines are required, whereas pipes of four inches in diameter have been assumed as the minimum, and since the introduction of steam fire engines, experience has proven that a line of four inch pipe will not properly supply more than one engine."—*Detroit Report for* 1862, *p.* 23.

"A difficulty is experienced in procuring from the hydrants now in use a sufficient volume of water to supply the steam fire engines. The same difficulty is experienced in other cities where steam fire engines have been introduced. This difficulty has been overcome in Philadelphia, by the substitution of hydrants operating in all respects like the ordinary one, except that the size has been increased, so as to give a clear water way of four inches. * * * The hydrants are fitted with three discharge nozzles, two for ordinary hose connexions, and one for the suction of the steamer. The introduction of hydrants of greater capacity is required here."—*Detroit Report for* 1861, *p.* 30.

The *protection* of hydrants, and their feed lines, *from frost*, is a matter of great consequence. The depths at which service mains are generally laid, viz: four feet, is supposed sufficient for their protection; in Brooklyn, the branches were laid for a hydrant base five feet below grade; cases, however, have occurred where mains and branches of small calibre have frozen, want of circulation being the cause.

The Cleveland Report of 1856, says;—

"Notwithstanding this precaution, (four feet depth,) the unprecedented and continued freezing weather of the past winter penetrated the ground to the depth of the pipes and below them. Several of the small lines at particular points were frozen solid inside with ice which burst them. * * * Six fire-hydrant connexions were frozen by exposure from the depth of the street gutters. To prevent a recurrence, the 3-inch branch-pipes will be laid deeper in future."

Report for 1857;—

"By reason of there being so very few water takers last winter, there was scarcely any circulation or current in the street pipes; (in some streets no water was taken at all;) much trouble and inconvenience was experienced during the intense cold weather. Some of the distributing pipes froze solid and consequently burst."

Report for 1863;—

"The operation of thawing out hydrants was performed 334 times last winter."

At Detroit in 1856, one-half the drinking hydrants and house service pipes were closed by freezing, and among the wooden logs, laid at shallow depths, of 1½, 2, and 2½ feet, four miles were entirely destroyed. The Report says;—

"The leaks from the freezing and bursting of iron pipes were comparatively few, and principally occurred where there was no circulation, and also where the streets have been cut down for paving since the pipes were laid. In one case where there was no circulation, a four-inch pipe, the top of which was four and a half feet below the top of the pavement, was frozen solid.

"As usual in this department, one man has been constantly employed in looking after and examining the fire-plugs and reservoir valves."

The cases of frost in service mains are exceptional and uncommon where much draft occurs, but the constant liability of fire-hydrants to freezing is well understood in all Northern cities. The Albany Report for 1859, says;—

"To maintain them in a working condition, daily examinations are necessary.

A few, in very exposed situations, are liable to be affected during severely cold nights, but early attention restores their efficiency, and preserves the pipes from disruption by the frost."

And the same rule holds in other localities. The Boston Report for 1858, says ;—

"The usual precautions have been taken to keep the hydrants in order during the winter. They have all been cleaned and oiled, also well packed with salt hay. They are all examined once, and sometimes twice a day, during the coldest weather, to keep them free from ice."

Report for 1859 ;—

"The unusual cold weather in the present month of January has made it necessary to keep an extra force of men employed to keep the hydrants free from ice, and in good order for use in case of fire."

The Detroit Report for 1857, sums up several contingencies thus ;

"Of the fire-plugs taken up and repaired, 6 were injured by freezing; 2 were broken in consequence of pebble-stones having been thrown in at the nozzle; the stones had fallen between the valves and seats, and in straining too hard to close the valves, they were broken off; one had the valve rod rusted off. The 7 fire plugs that were taken up and replaced with others, had been damaged by the frost past repair.

"Of the fire-plugs repaired without being taken up, 2 were broken by firemen; 5 were broken by frost; 2 were broken by cause not known. The 33 fire-plug boxes that were lowered and straightened had all been raised by action of the frost.

"From the above statement it will be seen that the action of frost is the principal cause of injury and damage to the fire-plugs. The fire-plugs in this city, which are the same as those used in every other city in the country, are unsuited to the severe tests of northern winters. A fire-plug that shall be so complete as to meet all the objections to the present kind, is a very great desideratum. From all places where they are used the same complaints are heard. The only remedies that appear to be applicable in their use, are to drain them, (as most of them are in this city,) and during freezing weather to allow none of them to be opened unless when required for use at fires."

The Chicago Report for 1861, says ;—

"The number of hydrants taken out to be repaired was 55,or about one in 8½ of the whole number in the city. Considering how seldom these are used for fires, the number repaired appears large. * * * Much pains is taken to keep the hydrants from freezing, by packing around them with manure in the beginning of winter, and by frequent examinations during very cold weather. Most of those found frozen are in boxes that are not drained, and consequently partly filled with water. Where sewers have been laid near hydrants, it is most desirable that the boxes around the latter should be connected with the former, as in excessively cold weather it is impossible with a reasonable force to keep all the hydrants constantly free."

Several instances are reported of hydrants being broken by heaving the case against the nozzle under the action of frost.

The method of frost vent adopted at Detroit in 1855, is thus stated :—

"The old waste cock and rod are dispensed with, and a small brass plug, with a quarter inch hole through the centre, is driven in, in place of the waste cock. A short piece of lead pipe is soldered on to the brass plug, and connects with the drain outside of the wooden box which encloses the fire-plug. The wooden box is then filled with earth up to the nozzle of the fire-plug. Of course, a quarter inch stream of water is wasted during the entire time that each plug is in use. * * * 128 of the fire-plugs are thus drained."

It does not appear, however, in subsequent reports that this method, with all its waste, was effectual, although some of the contingencies named in a former extract may refer to some of the 74 hydrants not thus drained in 1855.

A hydrant tube which is entirely encased, so as to hold a stratum of air around it, is less exposed to frost than one with solid stand-pipe head; a hydrant tube filled with water to the nozzle, is subject to frost above its valve, while an empty tube and a low valve are not so; and a narrow tube, with a large iron rod within it, aggravates the liability to frost; freezing also occurs when a case is filled in whole or in part with water, or with saturated packing of any kind. In severe weather, and during protracted fire-service, hydrants are apt to be opened and shut off a number of times, for changes of hose or engines, and their liability to saturated cases is thus increased, at a critical time.

In the various devices invented to ensure the desirable frost vents, absolute certainty of operation is not only requisite, but there should be a certainty of drainage, and one process is incomplete without the other; both are sufficiently simple, to be had without much ingenuity, and a vent which operates with the valve rod and at no other time, is evidently to be preferred to the wasteful devices above quoted. Neglect of drainage at Albany involved a troublesome and expensive reconstruction; this was in a clay soil; in Brooklyn, with a gravely soil, the precaution was taken to lay drain pipes not less than six feet long with six inches fall, from the hydrant bases.

Drains should connect with the street sewers, and not only ensure the case vent in this way, but maintain a current of warm air which is thus illustrated in the Chicago Report of March 31, 1864;—

> "About 100 hydrants have been connected with the sewers in such a way as not only to drain off waste and leakage from them, but to let warm air from the sewers circulate around them. Although the operation of thawing out hydrants was performed 334 times last winter, but one hydrant that was connected with the sewers was frozen, and that was owing to the drain-pipe having been obstructed."

For a frozen tube salt is frequently used; at Philadelphia a small boiler, easily transported on wheels, and so arranged as to apply a steam jet, inside and outside the tube, has been found a very effective corrective.

Hydrant *cases* are made both of wood and iron; as the special action makes them alternately wet and dry, durability is out of the question for the former material, and much trouble and expense is occasioned by its use. At Boston, as fast as the original cases decay, those which are substituted are Burnettized; in this way a cheaper case than cast iron and more permanent than the originals, is obtained. Some idea of city experience on this point is contained in the following statement;—

> "Many of the upper boxes have been repaired, while some have been replaced with new ones. In some localities the boxes decay rapidly, requiring frequent examinations."—*Albany Report for* 1860.

"The total number of hydrants is 255. * * * A large number of the boxes were found broken and decayed, some entirely detached from their fastenings. These, where practicable, have been repaired, while new ones have been substituted for such as were found entirely useless. As these repairs employed a mechanic and assistant for a long period, the expenditure for the same is large compared with that of former years. Every hydrant in the city was examined and put in order."—*Idem.*, 1861.

At Boston 127 Burnettized boxes were substituted in 1856, 176 in 1857, 148 in 1858, 83 in 1859, 123 in 1860, and 129 in 1861, 786 in six years, or more than half the entire number in 1861.

Of 367 hydrants repaired at Brooklyn in 1863, 116 required new covers, 107 new caps, 35 new boxes, and 64 new fastenings.

It might be supposed, simple law of cause and effect being ignored, that the experience of any one city, would settle the farther continuance or acceptance of such appurtenances, some of which, as at Albany, positively encumber narrow side-walks with their large proportions; but they still "increase and multiply."

The more convenient and durable iron cases, are therefore much preferable on the score of economy, but in time are subject to the effects of oxidation. Brick cases might be built, of ordinary or curved bricks; but cases made of concrete, in the same way as the best kinds of sewer pipes, with iron covers, could be substituted in such way as to combine the best qualities of form, cheapness and durability. Pipes of this kind may be made oval or circular, of any desirable thickness and strength, and bear exposure to alternate moisture and dryness, or frost and heat, without injury.

The propriety of using salt, hay, manure, earth, &c., for packing, is questionable, when the operation of the frost vent saturates it. Frost then becomes more certain and more severe, and thawing more difficult; a confined air stratum is much better, and in itself, an effective non-conductor.

As in all other appurtenances used in controlling or conveying water under pressure, the *workmanship* of a hydrant should be carefully made. At Philadelphia and many other cities the contract system is ignored, and all such details are manufactured under the direct inspection of the proper officers. There is considerable difference in the work of hydrant builders, the more pretentious not being always the most faithful. As to the castings, the valve seats, nozzle-bosses, and working gear, the best materials should be used and fitted in the most accurate manner, to avoid the chapters of annual repairs contained in annual reports. To avoid water action on the internal rods and gearing the former should be coated with composition, and the latter made of the same material.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On Chemistry Applied to the Arts. By Dr. F. CRACE CALVERT, F.R.S., F.C.S.,

From the London Chemical News, No. 240.

BONES.—Composition of raw and boiled bones. The manufacture of superphosphate of lime. Application to agriculture. Bone black or char, and their use in sugar refining. *Phosphorus*, its properties, extraction, and employment in manufacture of matches. *Horn* and *ivory*, their composition and applications.

LECTURE I.

I shall not take up your time by making many preliminary remarks, but merely state that though the heads of the subject on which I intend to speak are not inviting ones, still we shall find as we progress that the study of the various matters which I shall bring before you is full of interest and instruction. Further it would be difficult to name subjects which better illustrate the ability of man to turn to profitable account the various materials placed in his hands, or to mention substances which have received more complete and skilful applications than those we shall treat of this evening.

BONES.—The composition of "green bones," or bones in their natural state, may be considered under two general heads, viz :—the animal matters, consisting of a substance called osséine and a few blood-vessels, and the mineral matters, chiefly represented by phosphate of lime and a few other mineral salts. The composition of bones has been examined by many eminent chemists, but the most complete researches are those, published in 1855, by M. Fremy, who examined bones, not only from various classes of vertebrated animals, but also from different parts of the same animal; and to enable you to appreciate some of his conclusions, allow me to draw your attention to the following table:—*

Composition of Bones.

Name of Bone.	Mineral Matter.	Phosphate of Lime.	Phosphate of Magnesia.	Carbonate of Lime.
Femur—Fœtus 6 months,	63·0	58·9		5·8
" Boy 18 "	61·6	58·0	0·5	2·5
" Woman 22 years,	60·1	59·4	1·3	7·7
" Man 30 "	63·2	57·7	1·2	9·3
" " 40 "	64·2	56·3	1·3	10·2
" Woman 80 "	64·6	57·1	1·2	7·5
" " 97 "	60·8	51·9	1·3	9·3
" Lion (young)	64·7	60·0	1·5	6·3
" Sheep,	70·0	62·9	1·5	7·7
Sperm Whale,	62·9	51·9	0·5	10·6
Ostrich,	70·0			
Carapace of Turtle,	64·3	58·0	1·2	
Codfish,	61·3			
Stag's horn,	61 9	58·1	traces	3·8
Cow's tooth, Bone,	67·1	60·7	1·2	2·9
" " Enamel,	96·9	90·5	traces	2·2
" " Ivory,	74·8	70·3	1·3	2·2
Scales of the Carp,	34·2	33·7	traces	1·1

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* *Annales de Chimie et Physique*, volume xliii, pages 79, 83, 84.

The first conclusion drawn by M. Fremy from these researches is, that he found a larger proportion of mineral matter than is generally admitted by chemists. Secondly, that there is no material difference in the composition of various bones taken from different parts of man, or of any one animal, but that age had a very marked influence on composition. Thus, in the bones of infants there is more animal and less mineral matter than in the adult, whilst in old age there is more mineral and less animal matter than in the middle aged man. The mineral substance which chiefly increases in old age is carbonate of lime. Lastly, he could find no marked difference between the bones of man, the ox, calf, elephant, and whale; whilst in the bones of carnivorous animals and those of birds there is a slight increase in the amount of mineral matter. Allow me now to call your attention to a most interesting query. I hold in one hand the mineral matter only of a bone, which you can see retains perfectly its original form, and in the other hand I have the animal matter only of a similar bone, which also retains the form in which it previously existed, but is flexible instead of rigid. The question, therefore, arises, whether the strength and hardness of bones proceed from these two kinds of matter being combined together, or are their respective molecules merely juxtaposed? The answer is, the latter; for, as you see by this specimen, the mineral matter has been entirely removed without deforming the animal texture. Further, in the fœtus it is found that the bones contain nearly the same proportions of animal and mineral matters as those of the adult. Also, it has been observed by M. Flourens and other eminent physiologists, that the wear and tear of bones during life is repaired by the formation of new bone on the exterior surface of the bone, while the old substance is removed through the interior duct, and that the composition of the new layer is the same as that of the original bone. Let us now proceed to examine the chemical properties of the various substances composing bones, and some of the various applications which they receive in arts and manufactures. The general composition of bones may be considered to be as follows:—

Bones.

Organic Substances.	Blood-vessels,	1
	Osseine,	32
	Fatty matters,	9
Mineral Substances,	Water,	8
	Phosphate of lime,	38
	Phosphate of magnesia,	2
	Carbonate of lime,	8
	Various salts,	2
		100

The above-named animal matter, *osséine*,—

C	50·4
H	6·5
N	16·9
O	26·2

and which has been erroneously called gelatine, is insoluble in water, weak acids and alkalies, whilst gelatine presents properties directly reverse. But what has led to this popular error is that osséine, when boiled in water, becomes converted into the isomeric substance commonly called gelatine. As I shall have to dwell on this substance at some length in my next two lectures, I will not detain you now further than to state that osséine is obtained from bones by placing them in weak hydrochloric acid, which dissolves the phosphate of lime and other mineral salts, washing the animal matter (osséine) until all acid is removed, drying it, and treating it with ether to remove fatty matters. I cannot leave this subject without remarking on the extraordinary stability of this animal substance, for it has been found in the bones of man and animal after many centuries, and even in small quantities in fossil bones.

The fatty matter of bones is made useful in the manufacture of soap, railway grease, and in other purposes; it is obtained by taking fresh bones (as bones which have been kept a long time will not yield their grease easily) and placing the spongy parts, or ends of the bones (where most of the fatty matter exists) in large boilers filled with water, which is then carried to the boil, when a part of the osséine is converted into gelatine, and the fatty matter liberated, which rises to the surface, and is easily removed. The bones thus treated are called boiled bones, and receive many important applications, to which your attention will be called in a few minutes. Benzine and bisulphuret of carbon have been used as substitutes for water in the above operation, but the advantages do not seem to have been sufficient to lead to their general adoption.

Mineral Matter of bones.—These, as the foregoing tables show, are chiefly represented by phosphate and carbonate of lime. The immortal Berzelius was the first to establish the fact that phosphate of lime was the only substance possessing the properties necessary for the formation of bone, owing to the extremely simple chemical reactions which cause the soluble phosphates to become insoluble. Let us trace shortly the sources from whence we derive the large proportion of phosphate of lime which exists in our frames. Several of our most eminent chemists have proved the existence of phosphorus in sedimentary and igneous rocks, and the important part played by phosphorus in nature cannot be better conveyed to your minds than by this extract from Dr. Hofmann's learned and valuable Report on the Chemical products in the Exhibition of 1862:—"Large masses of phosphorus are, in the course of geological revolutions, extending over vast periods of time, restored from the organic reigns of nature to the mineral kingdom by the slow process of fossilization; whereby vegetal tissues are gradually transformed into peat, lignite, and coal; and animal tissues are petrified into coprolites, which in course of time yield crystalline apatite. After lying locked up and motionless in these forms for indefinite periods, phosphorus, by further geological movements becomes again exposed to the action of its natural solvents, water and carbonic acid, and is thus restored to active service in the organisms of plants and lower animals, through which it passes, to complete the mighty cycle of its movements into the blood and tissues of the human frame. While circulating thus, age after age, through three kingdoms of nature, phosphorus is never for a moment free. It is throughout retained in combination with oxygen, and with the earthy or alkaline metals for which its attraction is intense." After these eminently philosophical views by Dr. Hofmann, I will proceed to call your attention to the application of bones to agriculture. Bones are generally used for manuring in one of these three forms:—1st. As ground green bones; 2d. As ground boiled bones—(that is, bones nearly deprived of their osséine by boiling under pressure, as I shall describe in my next lecture); 3d. Superphosphate of lime.

Green or raw bones have been used on grass land for a long period, but their action is exceedingly slow and progressive, owing to the resistance of the organic matter to decomposition and the consequently slow solubility of the phosphate of lime in carbonic acid dissolved in water. What substantiates this view is that boiled bones are far more active than the above. It is found that 30 to 35 cwts. per acre of these will increase the crops on pasture land from 10 to 20 per cent. in the second year of their application. But the great advantage which agriculture has derived from the application of bones as a manure has arisen from their transformation into superphosphate of lime, especially applicable to root and cereal crops. To Baron Liebig is due the honor of having first called the attention of farmers (in 1840) to the importance of transforming the insoluble phosphate of lime of bones into the soluble superphosphate, rendering it susceptible of immediate absorption by the roots of plants, and of becoming at once available for their growth. These suggestions of Liebig were rapidly carried out on a practical scale by Messrs. Muspratt, of Lancashire, and J. B. Lawes, of Middlesex; and in consequence of the valuable results obtained by them, the manufacture of artificial manures has gradually grown into an important branch of manufacture in this country. The manufacture of superphosphate of lime is so simple that any farmer possessing a knowledge of the mere rudiments of chemistry can make it for himself, by which he will not only effect great economy, but also secure genuineness of product. All he requires is a wooden vessel lined with lead, into which can be placed 1000 ℔s of ground boiled bones, 1000 ℔s of water, and 500 ℔s of sulphuric acid sp. gr. 1·845 (or concentrated vitriol), mixing the whole, and stirring well for about twelve hours. After two or three days a dry mass remains, which only requires to be taken out and placed on the land by means of the drill, or to be mixed with water and sprinkled on the land. When very large quantities of this manure are required, the plan devised by Mr. Lawes appears to me the best suited. It consists in introducing into the upper end of a slightly-inclined revolving cylinder a quantity of finely-ground boiled bones, together with a known proportion of sulphuric acid of sp. gr. 1·68. As the materials slowly descend by the revolution of the cylinder they become thoroughly mixed, and leave it in the form of a thick pasty mass, which is conducted into a large cistern capable of containing 100 tons, or a day's work. This is allowed to remain for twelve hours, when it is removed, and is ready for use. Most manufacturers find it necessary to add to the phosphate of lime of bones other sources of phosphates, such as coprolites, or the fossil dung of antediluvian animals, which have been found in large quantities in Suffolk, Cambridgeshire, and elsewhere, and contain from 36 to 62 per cent. of phosphate of lime, and from 7 to 48 per cent. of organic matter. Others employ a mineral substance called apatite, containing about 92 per cent. of phosphate of lime, and found also in large quantities in Spain, Norway, France, &c. Others, again, employ guanos rich in phosphate of lime, such as those of Kooria Mooria Islands and Sombrero phosphates. The following is the average composition of the superphosphate of lime of commerce:—

Soluble phosphate, . . .	22 to 25 per cent.
Insoluble " . . .	8 " 10 "
Water, ...	10 " 12 "
Sulphate of lime, . . .	35 " 45 "
Organic matter, . . .	12 " 15 "

Nitrogen, 0·75 to 1·5 per cent.

The valuable and extensive researches of Messrs. Lawes and Gilbert and Messrs. Boussingault and Ville have not only demonstrated the importance of phosphates to the growth of cereal and root crops, but also that phosphates determine, in a great measure during vegetation, the absorption of nitrogen from the nitrates or from ammonia, as will be seen by the following table.

Amount of Nitrogen fixed by Wheat under the Influence of following Salts:—

	Without nitrogenated compounds.	With nitrogenated compounds.
Phosphate of lime and alkaline silicate,	8·15	20·08
Phosphate of lime, . .	7·25	19·17
Earth and alkaline silicates, .	5 71	11·16
Earth, . . .	3·00	9·50

Bone-black or Char.—In 1800 Löwitz made the interesting observation that wood charcoal possessed the remarkable property of removing coloring matters from their solutions. In 1811 Figuier also observed that animal black had far greater decolorating power than wood charcoal, and bone-black has consequently become one of the principal agents in sugar refining, and has been the means, more than any other substance, of producing good and cheap white sugars. To give you an idea of the extent to which bone-black is used at the present day for decolorating purposes in the refining of sugar, I may state that in Paris alone it is estimated that about 11,000,000 kilogrammes of bones are used annually for that purpose. The preparation of bone-black is simple in principle. It consists in placing in cast iron pots about 50 ℔s of broken boiled bones, that is, bones which have been deprived of their fat—of most of their osséine, and piling these pots in a furnace, where they are submitted to a gradually rising temperature during twenty-four hours, such as will completely decompose the organic matter, but not so high as to partly fuse the bones and thus render them unfit for their applications. But a more economical process is generally adopted. It consists in introducing the crushed bones into horizontal retorts, which are themselves in connexion with condensers, the ends of which are brought under the retorts to assist by their combustion in the distillation of the animal matter. By this arrangement not only is char obtained, but oily matters which are used by curriers, and also ammoniacal salts employed in agriculture and manufactures. The extraordinary decolorating action of animal blacks may be considered as partly chemical and partly mechanical--mechanical because it is proved, by some interesting researches of Dr. Stenhouse, to which I shall refer further on, that the action is due to the minute division of the carbon and the immense surface offered by its particles to the coloring matter, char being composed of 90 parts of mineral salts to 10 per cent. of carbon. On the other hand, the action is proved also to be chemical, by the fact that water will not remove the coloring matter, whilst a weak solution of alkali will dissolve it. Dr. Stenhouse's valuable researches not only illustrate fully this fact, but also prove the possibility of producing artificially substitutes for bone-black. In 1857 he published a paper describing the production of an artificial black, called by him aluminized charcoal. This he obtained by mixing intimately and heating finely pulverized charcoal and sulphate of alumina, when he obtained a powerful decolorating agent containing 7 per cent. of alumina, and well adapted for decolorating acid solutions, such as those of tartaric and citric acids, in chemical works. He also prepared what he called coal-tar charcoal by melting one pound of pitch in a cast iron pot, adding to it two pounds of coal-tar, and mixing intimately into it seven pounds of hydrate of lime, then carrying the whole to a high temperature, allowing it to cool, and removing the lime by washing the mass with hydrochloric acid and then with water, when carbon in a high state of division was obtained, possessing powerful decolorating properties. The following series of experiments by Dr. Stenhouse perfectly illustrate the chemico-physical action of animal black as a decolorating agent. He boiled a certain amount of char and his two charcoals with a solution of logwood, then treated each black separately with ammonia, when the following results were obtained;—Aluminized charcoal yielded no color; bone-black but a slight amount; coal-tar charcoal large quantities. But it would be wrong in me to leave you under the impression that animal black can only remove colors from solutions. Purified animal black—that is to say, animal black deprived of its mineral matters by the action of muriatic acid and subsequent washing—has the power of removing certain bitters from their solutions. Thus Dr. Hofmann and Professor Redwood applied this property with great skill some years ago to the detection of strychnine in beer. Again, Thomas Graham, Esq., Master of the Mint, published a most interesting series of researches, in which he established the fact that purified animal black had the power to remove a great number of saline matters from their solutions, such as the salts of lime, lead, copper, &c.

Revivification of Bone Black.—After a certain quantity of syrup sugar has percolated through the cylinders containing bone-black, the interstices become so clogged with impurities that it loses its power of decolorating the syrup. Sugar refiners are therefore in the habit of restoring the power of their bone-black, generally speaking, by submitting it to a process of calcination, which volatilizes or destroys the organic matter fixed by the char. It has been proved by experience that char may undergo this operation about twenty times before its pores become so clogged with dirt as to render it useless. [Here the lecturer described, with the aid of drawings, several of the various apparatus used in sugar refineries for the above process, alluding particularly to that of Messrs. Pontifex and Wood, by which a ton of char is revivified every 24 hours.] A new process, however, has been devised by Messrs. Leplay et Cuisinier, which as a whole deserves the attention of refiners, though I am aware that several of the details of their process have been used for some time. The char which has served its purpose in the cylinders, instead of being removed, is treated at once by the following processes:—It is first thoroughly washed, treated by steam to remove all viscous substances, then a weak solution of alkali is allowed to percolate through the char, which remove saline matters and a certain amount of coloring matter, when it is further acted upon by weak hydrochloric acid, which in removing a certain amount of the lime salts, liberates the coloring matter; the char is again washed with weak alkali to remove the remaining coloring matter, and lastly the decolorating power of the black is restored by passing through it a solution of biphosphate of lime. It is to be hoped that the high praise bestowed upon this process on the Continent may induce our manufacturers to try it, as they would obtain two distinct advantages by its use. First, the economy of operating at once upon the black and restoring its properties without removing it from the cylinders. Secondly, the prevention of the noxious odors given off during the revivification of char by the ordinary methods. It is interesting to note one of the results of the different employment of char in this country and on the Continent. In England the wear and tear in sugar refinery is constantly repaired by the introduction of fresh char, and there is no spent or old char for sale. In France, on the contrary, owing to the great impurities in their beet-root sugar syrups, and to the use of blood in refinery, the char become rapidly clogged with organic matter, and is so completely animalized, that its value as a manure exceeds what the char originally cost the refiner. The result is that the French "spent" char is annually exported to the French colonies to the amount of 120,000 tons, and is there used as a manure to promote the growth of the sugar cane. So important is this article of commerce considered, that the French Government have appointed special analytical chemists to determine its value for the trade.

Phosphorus.—I am now about to call your attention to one of the most marvellous and valuable substances ever discovered by chemists. In 1660, Brandt, a merchant of Hamburgh, discovered a process for obtaining phosphorus from putrid urine; but though he kept his secret, a chemist named Künckel published the mode of obtaining it from this fluid. A hundred years later, Gahn discovered the presence of phosphorus in bones; and Scheel shortly afterwards gave a process to obtain it therefrom. The process devised by this eminent chemist was shortly afterwards improved upon by Nicolas and Pelletier, and their method was so completely worked out by Fourcroy and Vauquelin, that it is still the process used in the present day. The preparation of phosphorus consists of four distinct operations:—1st, 80 parts of thoroughly calcined and pulverized bones are mixed with 80 parts of sulphuric acid, sp. gr. 1·52, to which is then added 400 parts of boiling water; 2d, after a few days the clear liquor, containing biphosphate of lime, is removed from the insoluble sulphate, and evaporated until it has the specific gravity of 1·5; 3d, this liquor is mixed with 20 per cent. of finely pulverized charcoal, and the whole is dried at a moderately high heat; when, 4th, it is introduced into an earthenware retort, placed in the galley furnace, and, on heat being slowly applied, phosphorus distils, and the operation is continued at a high heat for several days. It is, however, necessary that the phosphorus thus obtained should be purified, this is effected by melting the phosphorus under water, and pressing it through a chamois skin. It is then boiled with caustic alkali to remove other impurities, but what is still better is to heat the phosphorus with a mixture of bichromate of potash and sulphuric acid. The phosphorus thus purified is drawn through slightly conical glass tubes by the suction of a caoutchouc pouch, or is allowed to run, by an ingenious contrivance, into tin boxes. As will be seen by the following formula, the manufacturer only obtained from the bones one-half of the phosphorus they contain:—

$$\underset{\text{Bone phosphate of lime.}}{2\,(\mathrm{PO_5},\ 3\,\mathrm{CaO})} + \underset{\text{Sulphuric acid.}}{4\mathrm{SO_3HO}} = \underset{\text{Acid phosphate of lime.}}{2\,(\mathrm{PO_5CaO,2HO})} + \underset{\text{Sulphate of lime.}}{4\,(\mathrm{SO_3CaO})}.$$

$$\underset{\text{Bi-phosphate of lime.}}{2\,(\mathrm{PO_5CaO})} + \underset{\text{Carbon.}}{5\,\mathrm{C}} = \underset{\text{Pyro-phosphate of lime.}}{\mathrm{PO_5 2CaO}} + \underset{\text{Oxide of carbon.}}{5\mathrm{CO}} + \underset{\text{Phosphorus.}}{\mathrm{P}}$$

Consequently many attempts have been made to devise a chemical reaction by which the whole of the phosphorus might be secured. The most successful attempt of late years is that made by Mr. Cary-Montrand, whose process is based on the following chemical reaction:—

Action of Hydrochloric Acid on Bone Phosphate.

$$\underset{\text{Bone Phosphate of lime.}}{2\,(\mathrm{PO_5CaO})} + \underset{\text{Hydrochloric acid.}}{4\mathrm{HCl}} = \underset{\text{Acid Phosphate of lime.}}{2\,(\mathrm{PO_5,CaO,2HO})} + \underset{\text{Chloride of Calcium.}}{4\mathrm{CaCl}}$$

Action of Hydrochloric Acid on Bi-phosphate.

$$\underset{\text{Bi-phosphate of lime.}}{2\,(\mathrm{PO_5,CaO})} + \underset{\text{Hydrochloric acid.}}{2\mathrm{HCl}} + \underset{\text{Carbon.}}{12\mathrm{C}} = \underset{\text{Chloride of Calcium.}}{2\mathrm{CaCl}} + \underset{\text{Oxide of Carbon.}}{12\mathrm{CO}} + \underset{\text{Hydrogen.}}{2\mathrm{H}}$$

$$+ \underset{\text{Phosphorus.}}{2\mathrm{P}}$$

He arrived at this result by treating calcined bones with hydrochloric acid; the liquor is then mixed with charcoal, and the whole dried at a moderate heat. The prepared mass is then introduced into cylinders through which a stream of hydrochloric acid is made to percolate, and, as shown above, chloride of calcium, hydrogen, carbonic oxide, and two proportions of phosphorus are produced. (The process of Fleck was also described.) Phosphorus prepared and purified by the above processes is a solid, semi-transparent body, having a sp. gr. 1·83, fusing at 110·5° F., and boiling at 550°. It is so inflammable that it ignites in the open air at several degrees below its fusing point; but Professor Graham made, some years ago, the interesting observation that this slow combustion of phosphorus could be entirely checked by the presence of certain combustible vapors. Thus he found that one volume of vapor of naphtha in 1820 of air, or one volume of vapor of oil of turpentine in 4444 of air completely prevented the spontaneous combustion of phosphorus. Further, phosphorus presents the curious property that, if heated to 160° F. and suddenly cooled, it becomes black, and if heated to 450° or 460° for several hours it becomes amorphous, and of a dark brown color. This allotropic state of phosphorus, first noticed by Schrotter, has enabled it to render great service to society, owing to its not being spontaneously inflammable (as, in fact, it only becomes so at a temperature approaching its point of fusion), and also to its not being poisonous, so that it can be substituted for common phosphorus in the manufacture of matches with great advantage. Lastly, owing to this brown amorphous phosphorus not emitting any vapors, those employed in the manufacture of chemical matches now avoid the risk of the dreadful disease of the jaw-bone, called phospho-necrosis. Notwithstanding the great difficulties attending the manufacture of this valuable product, Mr. Albright, of Birmingham, has, with praiseworthy perseverance and great skill, succeeded in obtaining it perfectly pure on a large scale, and at such a price as to bring it within the scope of commercial transactions.

Chemical Matches.—Although I do not intend to enter at great length upon this subject, yet, as is a highly important one, I deem it my duty to lay a few facts before you. The first application of chemistry to the discovery of a substitute for the old tinder-box of our fathers, was made in 1820, when the sulphuretted ends of matches were covered with a mixture of chlorate of potash, licopodium, and red-lead, and the matches so prepared were dipped into asbestos moistened with sulphuric acid. In 1836, lucifer matches were first introduced, and the explosive matches were soon followed by the non-explosive ones. The composition of these matches is as follows:—

	Non-Explosive.	Explosive.
Phosphorus,	25 or 30	9 or 4
Red lead,	5 " 20	16 " 3
Nitre,	0 " 0	14 " 10
Sand,	20 " 20	
Vermillion,	1 " 0	
Gum or glue,	20 " 25	16 " 6

The danger as well as the disease attendant on this manufacture was greatly mitigated by Professor Graham's discovery of the property of turpentine vapor already alluded to. Until lately the only successful application of amorphous phosphorus to lucifer matches was that of Messrs. Coignet, Frères, of Paris, who caused a rough surface to be covered with it, and so prepared their matches that they would not ignite except when rubbed upon the prepared surface. Similar matches under the name of "special safety matches," have also been introduced into this country of late by Messrs. R. Letchford and Co., who have also effected several important improvements in this branch of manufacture, in one of which paraffine is made use of to carry combustion to the wood, instead of sulphur, which gives rise to the noxious fumes of sulphurous acid, and as the substitution is made by Messrs. Letchford without any increase of cost, the price of these matches is as low as that of the common ones. These gentlemen have also found the means of diminishing the amount of phosphorus used to a very considerable extent, so that the disagreeable smell of this substance is also avoided. But the greatest improvement that Messrs. Letchford have made is in what they call their hygienic matches, or lights, in which, for the first time, amorphous phosphorus is substituted for ordinary phosphorus, and in small quantities. The advantages of these matches cannot be overrated, for children can eat them with impunity, as amorphous phosphorus is not poisonous; they are not nearly so combustible, and, therefore, not so likely to cause accidental fires; and lastly, all source of injury to the health of those employed in the manufacture is removed. I cannot leave this subject without still drawing your attention to one or two important facts. Messrs. Hochstetter and Canouil, besides others, have lately introduced chemical matches free from phosphorus, which are stated to have the following composition :—

Chlorate of potash, . . .	10	10	10
Hyposulphide of lead, . . .	26	26	20
Peroxide of lead, . . .	—	9·8	—
Peroxide of manganese, . .	—	—	33·6
Chromate of lead, . . .	17	4	8 8
Gum arabic, ...	4	4	4

An important improvement in the manufacture of chemical matches is the reduction of the proportion of phosphorus to a minimum. This is effected by reducing the phosphorus to an infinitesimally minute division, by which the manufacture is rendered more economical, and the matches, when ignited, have less of the unpleasant odor, of phosphorus. This division is accomplished by using a solution of phosphorus in bisulphuret of carbon, by which a saving of $\frac{19}{20}$ths of the phosphorus is obtained. Another invention is that of Messrs. Puscher and Reinsch, who have proposed the employment of sulphide of phosphorus.

Ivory.—The lecturer, having given some details respecting the properties of ivory, said: I will now call your attention to the substitution of the following mixture for ivory tablets as applied in photography. Finely-pulverized sulphate of baryta is mixed with gelatine or albumen, compressed into sheets, dried, and polished; these sheets are ready for use in the same way as ivory plates. You are all doubtless aware that the nut of the *Phytolephas macrocarpa*, of the palm tree tribe, has for many years been used in this country as a substitute for ivory, and it may be interesting to you to be made acquainted with the two following facts, viz., that the nut is composed of—

Pure cellulose,	81	per cent.
Gum,	6	"
Nitrogenated principles,	4	"
Water,	9	"
Total,	100	

and Dr. Phipson has recently published a method of distinguishing this vegetable ivory from the animal one by means of sulphuric acid, which gives a beautiful purple color with the vegetable ivory, but none with the animal ivory.

Horn.—The best quality of horns, and especially the beautiful ones obtained from the buffaloes in India and America, receive a great variety of application at the present day, owing to their great toughness and elasticity, as well as to their remarkable property of softening under heat, of welding, and of being moulded into various forms under pressure. To apply horns to manufacture they are treated as follows:—They are first thrown into water, and slight putrefaction commences, by which ammonia is produced, when the horn begins to soften. To carry this action further the horns are transferred into a slightly acid bath, composed of nitric and acetic acids, with a small quantity of various salts. When the horns are sufficiently softened, which requires about two weeks, they are cleaned and split into two parts by means of a circular saw, and these are introduced between heated plates, and the whole subjected to an intense pressure of several tons to the square inch. The plates may be moulds, and thus the horn may be compressed into any required shape. A great improvement has recently been effected in this branch of manufacture, which consists in dyeing the horn various colors. To accomplish this the horn is first dipped into a bath containing a weak solution of salts of lead or mercury, and then rubbing upon the horns impregnated with metallic salts, a solution of hydrosulphate of ammonia, when a black or brown dye is produced. Another method consists in mordanting the horn with a salt of iron, and dipping it in a solution of logwood. Of late, very beautiful white fancy articles have been produced from horn by dipping it first in a salt of lead and then into hydrochloric acid, when white chloride of lead is fixed in the interstices of the horn, which then simply requires polishing.

This lecture, as well as those which followed, were illustrated by numerous specimens and experiments.

(To be continued.)

What is an Inch of Rain?

From the Journal of the Society of Arts, No. 639.

The last weekly return of the Registrar-General gives the following interesting information in respect to rain-fall:—"rain fell in London to the amount of 0·43 inch, which is equivalent to 43 tons of rain per acre. The rain-fall during last week varied from 30 tons per acre in Edinburgh to 215 tons per acre in Glasgow. An English acre consists of 6,272,640 square inches; and an inch deep of rain on an acre yields 6,272,640 cubic inches of water, which at 277·274 cubic inches to the gallon makes 22,622·5 gallons; and, as a gallon of distilled water weighs 10 ℔s, the rain-fall on an acre is 226,225 ℔s avoirdupois; but 2240 ℔s are a ton, and consequently an inch deep of rain weighs 100·993 tons, or nearly 101 tons per acre. For every 100th of an inch a ton of water falls per acre." If any agriculturist were to try the experiment of distributing artificially that which nature so bountifully supplies, he would soon feel inclined to "rest and be thankful."

Rain.

From the Journal of the Society of Arts, No. 640.

In the *Journal* of last week, under the title, What is an inch of rain? appeared an extract from the weekly return of the Registrar-General respecting the rain-fall. M. Petit, the director of the Observatory of Toulouse, speaking of the late heavy rains, says: "The quantity is not so unusual as at first sight would appear. The average annual fall is about 60 centimètres, rather more than two feet English, spread over about a hundred rainy days, thus giving an average fall of about six millimètres for each day, or about six litres, 10 to 11 pints English, per square metre. The average of the heavy rains of the 15th, 16th, and 17th of January, in the present year, rose to about nine millimètres. Greater falls have often occurred in France. On the 19th of September, 1844, 35 millimètres of rain fell at Toulouse in thirty minutes; and on the 10th of August, 1859, there fell 59 millimètres in two successive storms of about forty minutes each in duration. . . In recalling the impression of terror created by the sight of a precipice one is inclined to ask how it is that we are not terrified at such enormous quantities of water being suspended over our heads. But the question appears under a still more extraordinary aspect when we consider the amount of heat required to vaporize all the water which we receive in the form of rain. When we remember that in the tropics there falls about two metres of water per annum; that in our climate we have never less than 50 or 60 centimètres; and that the masses of snow in the polar regions must also furnish a great quantity of water, it will readily be admitted that the annual rain-fall must be, at least, equal to a stratum of water all over the globe of 50 centimètres, upwards of 19½ inches English. . . . It is easy, with these facts given, to see that the evaporation caused by the heat of the sun must render to the atmosphere about 175,000,000,000 cubic metres of water per day, or rather more than 2,000,000,000 of litres a second. . . . And yet the furnace is 38 millions of leagues distant from us!"

The Invention of the Screw Propeller.

From the London Mechanics' Magazine, February, 1865.

The well-known story of the king who, when he wished to read any of the historical works in his library, used to request his attendants to hand him his liars, seems likely to be repeated in the history of inventions. The future historians of achievements of this kind have a difficult task before them. They will have to meet all sorts of difficulties. However many lying *Te Deums* or thanksgivings may be proffered up for soi-disant victories, the truth about such an event as a great battle must, sooner or later, leak out pretty clearly. Not so with a great invention; and every civilized nation puts forward a separate claimant for almost every separate scientific victory. And then we know precisely what does constitute a victory by the force of arms; but we have not yet settled what constitutes an original invention. Is the first inventor the man who first has the idea, who first makes a sketch of the new thing? Or is it the man who first practically demonstrates it, and who then—like many inventors—throws it aside? Or is it the man who first clearly sees the commercial value of the thing (for an invention without any commercial value is still-born), and who dins this estimate into everybody's ears? Is the first inventor the man who first makes a drawing of the thing? or he who first makes it? or he who first (say) forms a company to work it? Does carrying out a thing, and then throwing it to one side, do away, more or less, with the first claim to the invention?

If we take, amongst other inventions, that of the screw propeller, we find that it is claimed by almost every great nation. England, France, America, Germany, and even Sweden, all enter the lists, and it is also claimed by the Chinese. Much might be said on this matter, but the rules as to scientific priority, in pure science, can scarcely be said to be laid down, and the question of scientific priority becomes doubly complicated when applied to technical matters. Of all claimants for inventions the most enterprising annexations of this kind are conducted by the French. It need scarcely be said that claims are made in France for this invention also. The chosen one is M. Frederic Sauvage, who, on the 28th of May, 1832, obtained a French patent for propelling a boat by two screws, one working under each quarter. A yet earlier proposition, however, for the adoption of the screw for ships was made in Germany. On the 11th February, 1827, an Austrian patent was granted to Joseph Ressel, an Austrian, for his invention of the Archimedian screw propeller, to be placed in the dead wood of the vessel; or for the use of two screws, one to be placed under each quarter. The Federal Diet have erected a statue to his memory at Trieste, and the Austrians another one at Vienna. In the latter city it is placed in front of the Polytechnic Schools. Some five years ago the Emperor of Austria also granted a pension for life to Ressel's widow.

In none of these cases does anything seem to have been carried into practical effect. If a mere sketch of the first idea is a sufficient basis for a national claim of this kind, we may point to the correspondence of Watt, more than a century old, as containing a very clear drawing of a "spiral oar." This was very much like the screw patented by Mr. Lyttleton in 1794, and long after by Mr. F. P. Smith. A specification of 1800, in the name of Shorter, also shows a two bladed propeller. The next was the patent by Richard Trevithick in 1815. Mr. Wilson, now of Patricroft, states that he experimented with screw propellers in the years 1812, 1825-7, and that his plan was proposed to Government by the Earl of Lauderdale, with the usual negative result. It was publicly tried, and he was rewarded for its success by the silver medal of the Society of Arts. Mr. Wilson then seems to have given up the thing, and to have settled down at Patricroft. Other Scottish engineers also experimented with screw propellers in 1829 and 1830. Records of their trials may be found in the Transactions of the Scottish and of the London Societies of Arts. All these practical doings were remote enough from the date at which the invention, or at least the introduction, of the screw propeller is generally fixed. But we have heard from a very good authority in such matters, that the late Mr. Stevens, of New York, the same wealthy inventor who first experimented with iron-clads, also, as long ago as 1812, or thereabouts, actually built and worked a screw propeller at Hoboken. If this be the case, it is to be hoped that a full account of his doings will soon be laid before the public. There is a *prima facie* probability here in favor of Mr. Stevens, in the mere fact that he was wealthy. As a rule those who invent have not the money to try and prove their ideas, while those who have the money do not care to invent—such favorites of fortune find things pretty well as they are already. But in the very fact of not caring for gain, and only seeking a sort of elevated pleasure in invention, they do not care to introduce their inventions. This seems to have been the case with Mr. Stevens, and the battle of the introduction and indeed the invention of the screw propeller, had to be fought over again.

In an article which appeared in the *Times* lately, on the "Patriarchal Engines at South Kensington," an erroneous statement is made with reference to the introduction of the screw. The writer says, "that to Mr. Pettit Smith, the present Curator of the Patent-Office Museum, belongs the credit of placing the screw propeller in the dead wood of the ship, *the only spot* in which it can work *effectually*, and of asserting the value of the new principle so long and so loudly as to force it upon the attention of the Admiralty." Now it so happens that the Screw Propeller Company, who bought Mr. Smith's patent, brought an action, in the name of their secretary, Buck, against Steinman, for placing the screw in the position in which screws are now generally worked. This cause was tried before Lord Chief Baron Pollock and a special jury, on the 10th January, 1846, in Westminster Hall, and it was then clearly shown that placing a screw behind the stern-post of a ship and before the rudder, was not the discovery of Mr. F. P. Smith. This position for placing the screw was shown, not only in the specification of Charles Cummerow's patent, in 1828, but also in Mr.

Bennet Woodcroft's specification of 1832—in the first case eight, in the second, five years before the date of Mr. Smith's patent. The chief particulars of this case will be found at page 48 of our 44th volume. In the summing-up the judge observed "that the great question was whether, where a vessel had been lengthened out beyond the ordinary dead wood, as in this case, and had had the screw fitted into that elongated part, that application could, in truth and fairness, be considered a violation of Smith's patent." The jury "found that the screws in the vessels named were not fixed and worked in the dead wood, and, secondly, that there was not a colorable evasion of Smith's patent in the mode by which the screw was applied to the same vessel." It is clear to any one who looks at the drawing attached to Mr. Smith's specification that he does not place the screw behind the stern-post, where propellers are usually worked. In fact, he places it so far in front of the stern-post and under the ship, that, in a vessel of 300 feet long, the screw would be more than 20 yards in front of the stern-post, and in a part of the ship where its diameter would necessarily be so small as to render it of little, if any, effect as a propeller. Again, the screw opening shown by Cummerow and others, and adopted by Mr. Smith, after having abandoned his own scheme, is not in "the only spot in which a screw can work effectually." Now the first boats practically propelled by screws had them working, not only behind the stern-post, but even behind the rudder. Again, it has been proved by Mr. Richard Roberts, that two screws, one under each quarter, form a better arrangement than one, and it seems likely that the place in a ship where screws have hitherto been worked will be now abandoned. The chief propelling power in Mr. Smith's company consisted in its aristocratic elements. The company's steamboat, the "Archimedes," made her first experimental trip on or about the 14th of October, 1839; and when these trials were over, the engines were taken out of her and she was sold for a sailing vessel.

It would have been contrary to the fact to suppose, as is asserted by the *Times*, that the Admiralty adopted the screw propeller in consequence of the "long and loud assertions" of its value made by Mr. F. P. Smith's company, or by an inspection of the "Archimedes." In fact, two years before, the Lords of the Admiralty had been towed in their own barge from Somerset House to the works of Mr. Seaward, and back, and at the rate of ten miles an hour, by a screw propeller boat the "Francis B. Ogden," made by Captain Ericsson. Amongst those present on this truly important experimental trip were Sir Chas. Adams, Senior Lord of the Admiralty, Sir William Symonds, the Chief constructor of the Navy, Sir Edward Parry, Captain Beaufort, and the designer of the vessel, Captain John Ericsson. The British Admiralty took no further notice of the invention at the time, but the experiment was being watched by a captain of the United States Navy, then in London, who saw the value of the invention for ships of war as well as for other vessels. He immediately ordered an iron screw boat from Captain Ericsson, and to be named after himself, the "Robert F. Stockton." This vessel was, probably, the first practical screw propelled boat that the world ever saw, and it was most certainly the first vessel of the kind ever set to work in British waters.

The undivided honors of having built the first practical screw steamer, the first screw war ship and the first cupola war vessel, thus belong to Captain John Ericsson. The "Robert F. Stockton" having demonstrated to English engineers the value of the screw propeller, sailed from England to the States in April, 1839. A special Act of Congress was obtained to allow her to ply in American waters and her name was changed to that of the "New Jersey. Before Captain Ericsson's departure for America he built another propeller boat termed the "Enterprise," for Mr. John Thomas Woodhouse. She first ran as a passenger boat on the canal at Ashby-de-la-Zouch, and she is stated to have been afterwards employed as a tug on the Trent and Mersey for a certain coal traffic, and with great success. This vessel actually begun to work before the "Archimedes" was constructed. If Mr. Smith had never once made experiments with a screw propeller, there would have been at this moment just as many boats propelled by a screw. On his arrival in the States, Captain Ericsson built the first screw vessel of war, the "Princeton," and she was launched in the month of April, 1842. Not even Mr. F. P. Smith could persuade the British Admiralty to try the screw, and Captain Coles was as unsuccessful with his cupola vessels. That the screw propeller has been applied to vessels of war; that the cupola system has been tardily and reluctantly tried, are due to the lessons, or rather warnings, wafted over the Atlantic. About a year after the launching of the "Princeton," we got our "Rattler," and just as the "Warrior" and her sister ships are British offspring of the "Gloire" and the other French iron-clads, so shall we be some day indebted to the American "Dictator," and her compeers for a trial of the cupola system.

Another error in the *Times* article consists in ascribing to Mr. F. P. Smith the construction of "the screw of the 'Rattler' which, in the water tournament, so signally defeated the paddle steamer 'Alecto.'" If the writer in the *Times* had only taken the trouble to open the catalogue of the museum, or make an inquiry of Mr. F. P. Smith himself, he would have seen that the screw in the Patent-Office Museum which performed the above feat was furnished by Mr. Woodcroft. This screw was made under a patent which he obtained in 1832 for an increasing pitch screw, and for which propeller the Admiralty paid him £220. This very patent was also prolonged for six years, although the prolongation was opposed by Mr. Smith's Screw Propeller Company. During the trial its relative merits, compared with the "Archimedean" screw, patented by Mr. F. P. Smith, in 1836, and previously patented by Wm. Lyttleton, in 1794, drew from Lord Brougham, one of the Judicial Privy Council then sitting, a remarkable expression of opinion. He said "as to the merits of the invention:—In this case there appears to be no doubt whatever; the evidence of all the scientific men, and all the practical men who have been examined before their lordships, appears to prove that it is an invention, we should say, as far as it appears before us, original, and also, as it appears before us, of very considerable merit and value. It appears to my mind that there is a clear step made in the progress of steam navigation, and in the construction of that very useful implement in steam navigation, the "screw" for the purpose of propulsion. It is introducing a new mathematical principle as well as a new mechanical principle, and I hold it to be a highly important improvement." When the "Rattler" was commissioned she was first furnished with three screws. One of these was that by Woodcroft, now in the Patent-Office Museum, another by Smith's Propeller Company, and one by Blaxland or Steinman. All the three were necessarily tried by the "Rattler" at Portsmouth before she joined the experimental squadron. Woodcroft's screw proved to be the best, and the two others were stowed away and never afterwards used. Captain H. Smith, the commander of the "Rattler" stated, in his sworn evidence before the Judicial Privy Council, "that she had been commissioned in 1844, by him. Several screws had been tried on her, and lastly that of Mr. Woodcroft. The results had been very good indeed." The following was a memorandum made at the time of the results which it had exhibited: "I think Mr. Woodcroft's spiral propeller superior to any yet tried in the 'Rattler.' It has less vibration, less fuel is consumed, with fewer revolutions and greater speed; consequently there is less slip. On the 25th of February, the result of going with a head wind blowing hard was better than any before." Mr. Langlands, the chief engineer of the "Rattler," was sworn, and stated, "that Mr. Woodcroft's screw gave greater speed, with fewer revolutions, less vibration, and used up the power of the engine better." It was by means of this screw that the "Rattler" was enabled to tow the "Alecto," and it drove the "Rattler" until she was no longer fit for service. If the *Times* would make use of its own old files, it would find that on the 4th of July, 1846, in speaking of the experimental squadron, then in the Bay of Biscay, it says that "with the exception of the "Rattler," which is, we believe, fitted at this time with Woodcroft's screw propeller, and which distinguishes herself on all occasions, under sail, as well as steam, the large steamers have proved large encumbrances to the fleet." The subsequent history of the screw propeller is, like most other histories of the kind, that of a succession of British and foreign patents.

New Safety Light for Coal Mines.

From the London Athenæum, Feb., 1865.

MM. Dumas and Benoit have been making some experiments in the French collieries on the application of electricity as an illuminating power in "fiery" coal mines. Voltaic electricity has been proposed on several occasions, as a means of giving light to the collier in dangerous places. But, under the ordinary conditions, it has not been found practicable to employ it. Dumas and Benoit propose to apply Rhumkorff's coil machine and Geissler's tubes; to use, indeed, those tubes, with their beautiful auroral light, as a miner's lamp.

The tube, it is now generally known, is filled with some highly rarefied gas, and platinum wires are hermetically sealed into the ends. When the discharges from a Rhumkorff's coil apparatus are passed through this tube it becomes filled with a mild, diffusive light, which lasts as long as the discharges pass through the rarefied medium. This light is unaccompanied by heat; it cannot, therefore, under any circumstances, explode the fire-damp of our coal mines.

This new "safety lamp" consists essentially of a cylindrical zinc vessel about 6 inches high and 4 inches in diameter, which incloses a porous vessel holding a cylinder of carbon. A solution of the bichromate of potash is placed *in* the porus cell, and dilute sulphuric acid *without* it. This battery is secured by a wooden cover, which is, by means of india rubber packing, made to fit closely. Then there are a Rhumkorff's coil and condenser, and a Geissler's tube. This tube is arranged into a conical coil, so that a large surface of light is secured within a small space. Of course the objection to this will be the cumbrous character of the machine and its adjuncts. Dumas and Benoit think they have answered this objection by the very ingenious arrangement which they have secured. We are assured that the weight of the glass case does not exceed two pounds, and that of the other parts of the apparatus is not more than twelve pounds. That there are many advantages in this electrical lamp cannot be denied. But we doubt if so delicate a machine can be intrusted to the hands of colliers. Under circumstances of danger, such a lamp as this would prove of the highest value. As Dumas and Benoit are making practical trials of their "cold light" as they call it, we shall, if they are successful, hear more of this interesting application.

The Institute of France has given the inventors a prize of 1000 francs for the ingenuity of their plan. We understand that some trials have been made in the Newcastle collieries. The objection raised by the miners is, that the light is a "glimmer"—not a steady illumination.

For the Journal of the Franklin Institute.

The Economy and Safety of different Modes of Traveling. By Wm. Bouton, University of Michigan.

The purposes of the traveler are so various that the mode which is most economical for one purpose may be very expensive for another. If the purpose is to storm a battery, there is no way quite equal to going on foot.

Some noted travelers have commenced their career by journeying on foot over the most populous countries of Europe, and have even had the audacity to recommend it as the fittest mode for one, who wishes to see the sights and learn the customs of those nations.

If a man should set out to seek the head-waters of the Nile with the thought that civilized man had never trod the path before him, a *locomotive engine* would be as much out of place in his outfit as a panorama of Paradise Lost printed on six thousand feet of canvass.

But these purposes generally involve the common desire to reach the journey's end with the greatest possible *rapidity*, *ease*, and *safety*, and with the least *cost*.

The mode of travel which at the same time secures all these requirements in the highest degree will be preferred. Or since perfection cannot be attained, a great gain in one, speed for example, will be chosen at some loss in another, as safety.

What are the exact equivalents of each, in terms of the other, or how far any one of them may be sacrificed for a given gain in another, it is difficult to say. It rather is evident that no two men would judge of them and agree. One man thinks more of his ease: another will make great exertion to avoid most distant danger: a third values his time and is willing to take greater risk, so he can accomplish more. Yet all will agree practically, that speed, safety, ease, and cost of travel, are each convertible in terms of the other between *some* limits. The prudent man never lived who would always drive a spirited horse at a walk, though it might be much safer to do so.

Formerly, perhaps yet, public opinion regarded railway traveling as much more dangerous than the time-honored system by stage coaches. Men traveled by railroads nevertheless, and stage coaches had to migrate. This does not prove, that when men made the charge against railroads, of greater danger, they were insincere. They valued the increased speed and cheapness as well as ease, more than they regarded the difference in safety. A journey of 300 miles, but an ordinary day's ride by rail which gave the night for rest, would consume four or five days in comparatively hard work by stage, and without half the certainty of making connexions between different lines. The stages charged *six* cents a mile more or less for fare, the railroads charged *three* cents. These advantages, too palpable to be overlooked, revolutionized the world's travel. Greater *safety* was not generally believed in.

If now it shall appear by an examination of statistics that the danger of accident on railroads is really much less than by the old methods or by existing modes of canal and river packets, it will result that in speed and safety, as to cost and comfort, railroads stand pre-eminent.

A railroad accident occurs; everybody hears of it. The newspapers are filled with glaring capitals and detailed accounts of how it all happened. Who ever heard of a stage coach accident being published outside the county journal. The impression gains that railroads are very destructive to life.

To judge justly let us reduce the statistics to some standard of comparison. When we can get the necessary data, let us compare the number of casualties with the whole number of miles traveled on any road. This ratio is more satisfactory than any other, for we wish to know the danger in accomplishing a given journey, whether it be crowded into a day or spread out over a week.

On the railroads of New York State in 1853, a little more than twelve millions of passengers were carried an aggregate distance of 531,512,298 miles, 15 persons were killed, or 1 in 35,434,153 miles traveled. But a large majority of these accidents resulted from getting on or off the train when in motion, standing or lying on the track and the like. If we exclude these, but three fatal accidents remain or 1 in 177,170,766 miles traveled. In the Cyclopædia of Commerce, 1860, I find that in New York, for a series of years, the average loss of life was 1 person killed for 47,164,426 miles traveled. If, as before, we exclude accidents arising from the sufferer's own carelessness the ratio is 1 in 235,822,132. These results are tabulated from the State Reports. In the same publication for the year 1863, I find that Dr. Lardner has estimated the chances of a fatal accident per mile of railroad travel, 1 to 65,363,735. The chances of injury, 1 to 8,512,486. Such an estimate from so eminent an authority is entitled to much weight. We see that the range is very wide; we should also find the danger on some roads and in some sections of country uniformly greater than in others.

Taking Dr. Lardner's estimate and allowing 300 miles as a day's work, traveling by rail, a person must travel 597 years before there would be an expectation of a fatal accident, (I refer here to the mathematical and not the moral idea of expectation.) Reductions on the same basis, from some of the figures given above, would give over 2000 years before the expectation of a fatal accident to the traveler on those roads. Are not fatal accidents quite as common in the ordinary business of life, as on railway trains?

In Hunt's Merchants Magazine, vol. xxxix, page 249, a table is given of the casualties from railway traveling in England, Scotland, and Ireland for the years named, formed by dividing the total number of passengers by the number killed, as follows:—

Year.	Ratio as above.	Year.	Ratio as above.
1850	6,071,202	1855	11,859,513
1851	4,494,268	1856	16.168,449
1852	8,913,572	1867	5,200,000
1853	2,841,296		
1854	9,529,907	Mean,	8,137,276

In order to compare this table with the results given above on other roads, I find in the Cyclopædia of Commerce for 1859, data from which it results that the average distance traveled by each passenger in the United Kingdom during this time was 16 miles very nearly. Hence we find that there was one fatal accident in 130,196,416 miles traveled.

The following table shows the comparative safety of railway traveling in different countries, compiled, the writer says, from the statistics of a series of years. It would seem that there must have been a very large proportion of wounded to make these figures agree in the case of England with those just given for Great Britain. Hunt's Merchants Magazine, vol. xxxix, page 504.

Prussia,	1	killed or wounded for		3,294,075	carried safely.
Belgium,	1	“	“	1,611,237	“
France,	1	“	“	375,092	“
England,	1	“	“	311,345	“
United States,	1	“	“	188,459	“

In seeking an explanation for these figures I have found that the average travel of each passenger in the United States is about forty miles while in Great Britain it was but 16 miles, or if we multiply the ratio in the United States by the average distance traveled by each passenger, we shall have for the ratio of casualties to the whole distance traveled, $188,459 \times 40 = 7,538,360$. A little more than 12 per cent. more disastrous than the mean given by Dr. Lardner.

How was it in the good old times of stage-coach traveling? Statistics were rare. I have been able to find the following:—

On French railroads 212 miles in length, of 1,889,718 passengers who traveled over 316,945 miles, in the first half of 1843, not one was either killed or wounded, and only three servants of the railroad suffered. Comparing with this, the traveling by horse coaches in the *same region* we find that in seven years, from 1834 to 1840, 74 persons were killed, and 2073 wounded.—*Gillespie's Roads and Railroads.*

In Hunt's Merchants Magazine, vol. xxxix, I find that under the postal system of France, 1846 to 1856, of 7,109,276 passengers, 20 were killed and 238 were wounded. This was after railroads were introduced which accounts for the small number of passengers, but I do not quite see how it accounts for the large proportion of accidents,—1 killed or wounded for 27,555 carried safely. More than six times as disastrous as the worst show that has been made among all the systems of railroads examined. On an American railroad, traveling 30 miles an hour a traveler is safer than in a French diligence, traveling 5 miles an hour!

If we consider fatal accidents only, the ratio is 1 to 355,463, more than 22½ times the ratio of fatal accidents to the number of passengers on railways of Great Britain for the same period!

Some of the reasons for this great difference are the system to which railroad management has been reduced so as always to fix the blame where it belongs; the great strength with which the cars are made so as even to collide at high speeds and only smash the engine and baggage car; the smoothness of the road, freeing the wheels and axles from such severe jolts and strains as they are liable to on common roads; the centre of gravity of the cars is lower, hence they are less liable to be overturned, the engine does not take fright and is at least more manageable than a vicious horse.

The following statistics of the loss of life by *steamboat* accidents may be interesting. The figures include the lake, river, and harbor casualties of the United States in the years mentioned.

1853	576 killed.	1857	303 killed.
1854	587 “	1858	364 “
1855	176 “		

We see that the loss of life was on the whole decreasing while the travel was increasing. I think it is evident that the proportionate loss of life is greater than on railroads, though I have been unable to determine the total amount of travel.

The statistics of canals which I have found, refer to the economy with which they carry freight and not their value as lines of travel.

The following table gives the number of casualties from railroad accidents in the United States for eight years.

Year.	Number killed.	Number wounded.	Number of Accidents.	Average No. killed and wounded at each accident.
1853	234	496	138	5·28
1854	196	589	193	4·07
1855	116	539	142	4·61
1856	195	629	143	5·77
1857	130	530	126	5·24
1858	119	417	82	6·54
1859	129	411	79	6·83
1860	57	315	74	5·03

These figures show that while the number of miles of railroad was increasing 2000 to 3000 miles a year, and the old roads were increasing their business, still the number of casualties very steadily decreased. The last column shows that the accidents which did occur were as serious in 1860 as 1853 and 1854. Has this ratio decreased since that time?

In Great Britain from 1854 to 1860, after their railroad system was nearly completed, the yearly travel increased eight per cent. per annum. I cannot find as definite statistics for this country, but if we consider how each new road adds to the business of the whole and the rapid increase of the population, we shall be safe in assuming that on the old roads in this country the travel increased ten per cent. per annum for the same period. Combining with this the fact that from 1853 to 1860 the total length of railroads in the country increased from 17,000 to 31,000 miles and it will result that in 1860 the railway travel in the country was 3½ times what it was in 1853. If the number of accidents had maintained the same proportion, we should have had in 1860, 483 accidents and 819 lives lost by them, instead of 74 accidents and 57 lives lost. Even 1865 does not threaten to compete with 1853 in the danger of railway traveling. And in that year railroads were several times safer than any other mode of travel known.

If other testimony were wanting to prove the safety of railroad traveling, we might mention that in England, companies insure against loss of life and proportionately against injury from railroad accidents.

On a trip from London to Liverpool, 1 penny insures against loss of life for £ 500, and their reports show that for dividends, the stocks of the insurance companies are better than those of the railroads.

New Boiler Regulations in France.

From the London Artizan, Mar., 1864.

A ministerial decree has been issued in France relative to steam boilers. The following is a *résumé* of the chief instructions issued:—

Every boiler, new or old, before it is delivered by the constructor, repairer, or seller, is to undergo a proof under the direction of Mining or Ponts et Chaussées engineers. This proof consists in submitting the boiler to a pressure, double of what it is not to exceed when it is working, for all boilers of a working pressure between half a kilogramme and 6 kilogrammes per square centimetre (7·1 lbs and 85·3 lbs per square inch) exclusively. The surcharge of proof for pressures under these limits is to be constant and equal to half a kilogramme per square centimetre; for pressures higher than the superior limit the surcharge is to be 6 kilogrammes per square centimetre. The proof is to be made by hydraulic pressure kept up as long as is necessary for the examination of all parts of the boiler. If the proof be satisfactory, a stamp indicating in kilogrammes per square centimetre the effective pressure that the steam should not exceed, is to be affixed to the boiler in such a manner as to be visible after it has been put in place. Two safety valves are to be provided for each boiler, to be weighted so as to allow the steam to escape before, or at least as soon as, the pressure arrives at the quantity marked on the stamp, placed in view of the fireman, showing the pressure of steam in the boiler. All boilers are to have apparatus of sufficient and effective power for supplying water to them. No steam boiler, to be employed in a building, is to be established without a declaration being made to the prefect of the department. Certain boilers are to be established only outside a house or workshop having an upper story where workmen are in regular employment. No boiler of the first class is to be placed at a less distance than 3 metres (9 feet 10⅛ inches) from a neighbor's habitation. All furnaces of boilers, of whatsoever class they may be, are to consume their own smoke. Six months delay is accorded to manufacturers to whom no notice was given at the time of authorization, to execute these last dispositions. The boilers of portable engines are to be submitted to the same proofs, and furnished with the same safety apparatus, as boilers established in a fixed place; so also are locomotive engines.

For the Journal of the Franklin Institute.

On the Means Adopted in the Factories at Lowell, Massachusetts, for Extinguishing Fire. By JAMES B. FRANCIS, Civ. Eng.

The first cotton mill at Lowell went into operation in the year 1823; it was provided with force-pumps which supplied a cistern in the roof and a hydrant in each story. There were no hydrants outside of the building. All the cotton mills erected in Lowell previous to the year 1828 were protected in the same manner. In January of that year a mill was burned down, and the want of some more efficient means for extinguishing fire was clearly shown. The plan was then adopted of laying an eight-inch main pipe through each mill yard, about forty feet in front of the mills; this pipe was furnished with hydrants, and was connected with the force pumps and roof cisterns of each mill, so that all the apparatus on the premises could be brought to bear on any one mill. When the force pumps were not in operation, the supply and pressure of water in the mains depended entirely on the cisterns, but by means of a peculiar system of valves at the cisterns, a pressure equal to a head of one hundred and fifty feet, could be maintained in the main pipes when the force pumps were in operation.

The next improvement of importance was made in the years 1847 and 1848, when the main pipes in the several mill yards were connected, so that, as far as the capacity of the eight-inch main pipes would permit, the force-pumps in all the mills in the city, could be brought to bear on any one mill. In 1849, a reservoir was constructed on an elevation about a mile from the nearest mill, and connected with the main pipes in the mill yards by means of a twelve-inch pipe, through which the water passes, either from the mill yard mains to the reservoir, or the reverse, according to circumstances. When full, this reservoir contains about two millions of gallons, and gives a head in the main pipes in the mill yards, of from one hundred and eighty to two hundred feet. The supply of water in the reservoir is maintained by means of force-pumps, erected for the purpose, driven by water power. It was originally designed to limit the use of this water to the purpose of extinguishing fires; the high and constant pressure afforded, however, great advantages for supplying the steam boilers used for heating purposes in the mills. Water is drawn from the mains in most of the mill yards for this purpose. About a dozen dwelling houses are also supplied, and small quantities are occasionally drawn for building, and other purposes. The whole quantity drawn for other than fire purposes is, however, too small sensibly to affect the pressure in the pipes. The city having no public water works, urgent applications have been made for the privilege of tapping the pipes, but they are jealously guarded, as the efficiency of the whole system depends in a great degree upon maintaining a constant high pressure in the mains, which the experience of other cities, shows can scarcely be done, if the water is generally used for domestic purposes.

Previous to the year 1850, the large manufacturing corporations at Lowell had seldom effected any insurance on their property, against losses by fire, but had relied upon laying aside a portion of their earnings, as an insurance fund, to meet such losses as might occur. An efficient system of watching had been adopted from the first, and great care was constantly exercised in guarding against fire and in keeping up the apparatus for extinguishing it. In the year 1850, they entered into an agreement for mutual insurance; some modifications indicated by experience have subsequently been made in it; as now in force it imposes very little restraint upon the manufacturing operations, and provides for the distribution of all losses, among the co-insurers, in proportion to the irrespective capital stocks. Nothing, however is paid on losses of less amount than one thousand dollars, and no member is obliged to contribute more than two per cent. of its capital stock, on account of any one loss.

The aggregate amount of the capital stocks of the co-insurers is $13,600,000, and the amount of loss by any one fire, covered by the mutual insurance, is $272,000. Only the property within the limits of the mill yards is covered by the mutual insurance; no exact estimate of its aggregate value has ever been made, but when the usual stocks of materials and goods are on hand, it is supposed to be equal in value to about three-quarters of the capital stocks, or $10,200,000. The whole number of losses covered by the mutual insurance during the fourteen years and ten months since its adoption, ending April 14th, 1865, was fifteen, amounting to $141,818·32; the average annual loss being $9,560·79. If the value of the property insured is taken as above stated, the average annual loss has been a little less than one-tenth of one per cent.

The mutual insurance agreement provides a mode for ascertaining the amounts of losses, and also, for frequent inspections of the apparatus for extinguishing fire, and for the ejection and withdrawal of any of its members. Since this arrangement was entered into, there has been much interest felt in perfecting the apparatus, and great expense has been incurred in so doing. The lines of pipes through the mill yards and the connexions from one yard to another, made an irregular line of eight-inch pipe, about three miles in length, having a general horse-shoe form; the connexion of this line with the reservoir was at one point, near the toe of the shoe; in the year 1853, an important improvement was effected, by connecting the ends of the horse-shoe line, by a pipe of the same size, about three-quarters of a mile in length. Since this connexion has been made, the water drawn in any mill yard, from the reservoir, passes through the twelve-inch pipe to the eight-inch pipe, thence through both branches of the eight-inch pipe, to the place of delivery, or a point near the same. In each mill yard there are several sets of force-pumps, driven by water power, these are kept ready for immediate use; the water thrown by them is discharged directly into the eight-inch main pipe, and any excess of water, not drawn from the main passes up to the reservoir.

Each mill yard is supplied with numerous hydrants; on an average one to about every fifty feet in length of the main pipe at the front of the mills, and nearly as many at the rear; about one-third of these hydrants have one hundred feet of hose and a hose pipe constantly attached; these are protected from the weather by small buildings, in which the hose is hung ready for instant use. Supplies of hose are kept at hand for use at the other hydrants, and ladders with platforms at each story are fixed at several places on the sides and ends of the buildings; these serve for fire escapes for the operatives, as well as for purposes connected with extinguishing fire.

Lines of pipes, about four inches in diameter, are carried from the mains into the mills, passing up to the top, and having a hydrant at each story, with hose and pipe constantly attached.

As a rule, there is such a line at each stairway, the pipe and hydrant being placed inside the rooms, as near as practicable to the head of the stairs. This situation is preferred, as it enables the operators of the apparatus, to remain longer at their posts, and with more sense of security, than they could do at points from which escape would be less easy and certain. The mills built previously to 1845, were generally about 156 feet long, 45 feet wide, and four stories high, besides basement and attic; these mills have usually one stairway, placed in a projection or porch in the middle of the front. Mills of later construction are generally larger, and have two or more stairways, and a corresponding number of lines of pipes and hydrants. These pipes are constantly filled with water under high pressure, and the hydrants are kept ready for instant use.

It has been found by experiment that in one of the mill yards, least favorably situated, four of the hydrants outside of the mills, discharging through three-quarter inch nozzles, could be supplied at one time, and throw water to a vertical height of about seventy-five feet above the nozzles; when the number was increased to eight, the vertical height to which the water could be thrown was reduced to about sixty feet. In this experiment none of the force-pumps were in operation, the entire supply being drawn from the reservoir. In some cases, when the force-pumps in several mills were in operation, twenty-five or more hydrants have been effectively used at once. In case of fire, the nearest apparatus is got into use as soon as possible, and if there is any probability that a larger quantity of water will be wanted than can be supplied under a suitable pressure from the reservoir, the force-pumps in one or more of the mills are put in operation; if a very large quantity is wanted, the force-pumps in mills in other parts of the city are put in operation. A frequent result in such cases is that the quantity of water in the reservoir is greater after the fire than before; this arises from a greater number of force-pumps being put in operation than necessary, the excess of water pumped passing up to the reservoir. Safety-valves, similar to those used on steam boilers, are applied at several points on the eight-inch main pipe, to relieve it from excessive pressure due to the action of the force-pumps.

Sprinklers, within a few years, have been extensively introduced into the Lowell Mills, and in connexion with the system of reservoir and mains, are considered the most effective means known for extinguishing fire. In some of the departments of a cotton mill, fire spreads over a whole room with such rapidity, that hydrants or other ordinary means, seem to be wholly inadequate to extinguish it. In such case, a suitable sprinkler appears to afford the greatest protection practicable.

As constructed at Lowell, a sprinkler consists of a net-work of pipes perforated with small holes, so arranged and directed that when a valve connecting the sprinkler with the main pipes is opened, the water will flow into all parts of the system of pipes, and escape at the perforations, with sufficient force to wet thoroughly, and in a very short time, every part of the room it is designed to protect. The idea is not new or peculiar to Lowell,* but perhaps it has been more extensively and systematically adopted there than elsewhere. It was first introduced at Lowell, in the year 1845, into the picking-room of the Suffolk Manufacturing Company, by Mr. John Wright, the agent of that company.

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* A patent was granted in England in 1806, to John Carey, LL. D., of London, "for an invention of various contrivances for preventing or checking fires," &c. The invention first described in his specification is for a "shower bath for apartments, warehouses, &c. This is substantially the same apparatus as the sprinkler, with the exception that Carey's contrivance is intended to be put in operation by the fire itself. The cock by means of which the water is admitted to the apparatus containing the perforations for distributing the water, is furnished with a horizontal lever and a weight, sufficient to open the cock. This weight is held up by a cord which passes over different parts of the room; if this cord is burned off at any point, it allows the weight to fall and open the cock.

Repertory of Arts, &c., volume x, second series, London, 1807.

As is well known, this department of a cotton mill, is peculiarly liable to fire, from the action of the machinery on the cotton, and particularly on the foreign substances which are often found mixed with it.

After the construction of the reservoir, the advantages of the sprinklers, when used in connexion with it, were so obvious, that they were soon introduced into the picking departments of all the cotton mills in Lowell. In 1852 and 1853, sprinklers were put into the roofs of the mills. In one of the old mills, which have slated roofs, the plan adopted was to carry a six-inch pipe, from the main in the mill yard, up near the middle of the mill to the level of the perforated pipe, which was placed a few feet below the ridge pole, and extended the whole length of the mill, in a single line, gradually diminishing in size, from five inches in diameter, near the middle, to three inches at the ends. This pipe was perforated with two holes, $\frac{3}{16}$-inch in diameter, in each foot in length. These holes point in different directions, so as to wet, as far as practicable, all parts of the roof. The water after striking the roof, falls, and a large portion of it finds its way into the stories below. The valve connecting the sprinkler with the main pipe, is placed in or near the ground, usually in a pit in the ground, near the mill, so as to be always readily accessible, and the water being constantly maintained in the main pipe at a high pressure, the sprinkler can be put in operation with very little delay.

The roof sprinkler is deemed a very great security against heavy losses by fire, as it affords the means of applying a large volume of water at the top of the mill, where from the elevation it would otherwise be difficult to apply it. This apparatus is expected to discharge about four hundred gallons of water per minute, and is intended to be used only for a few minutes at a time, unless the fire is confined to the roof. Its efficient action requires that most of the hydrants should be shut off.

Between the years 1853 and 1859, sprinklers had been introduced into many of the carding and spinning rooms of the cotton mills, which rooms are particularly liable to the rapid spread of fire. In the year 1859, sprinklers were required to be put in all such rooms, as well as into all picking rooms, and all other buildings and rooms liable to the rapid spread of fire or of difficult access.

It has been found by experiment that about four hundred and fifty gallons per minute is the largest quantity of water which can be drawn from the main pipes in some of the mill yards, from the reservoir alone, and maintain an effective working pressure. If a large fire should occur at a time when the canals are drawn off, as they often are during the night and on holidays, to enable repairs to be made, the force-pumps could not be operated, and the supply of water would be limited to that which could be drawn from the reservoir. By operating one section at a time, the sprinklers can be effectively used in such an event; but in a large fire, the supply of water would be much too small for the efficient action of all the apparatus provided. The remedy is a larger main pipe, an improvement we are looking forward to in order to perfect the system.

As an illustration of the arrangement of sprinklers adopted at Lowell, the following description is given of the apparatus in the Tremont Mill, which was erected in the year 1863.

The building is about 440 feet long, and 70 feet wide inside; with five full stories and a roof nearly flat. The floors are of wood, supported by two rows of pillars. The beams are about 16 inches deep, placed about 8 feet apart. The floors are made of three-inch planks, laid directly on the beams, with a boarding above, and another below, between the beams, forming the ceiling. The three upper stories are furnished with sprinklers, arranged in three sections in each story. Each section is supplied by a rising main pipe, of cast iron, 6 inches in diameter, connecting with the eight-inch main pipe in the mill yard, and furnished with a stop gate, placed in a pit in the ground, deep enough to be completely protected from frost. The handle of the stop gate is constantly attached to the gate, and extends above the level of the ground, so as to be readily accessible at all times. The rising main pipe is carried up outside of the mill wall, and between the windows, in order to be out of the way of heat, when not filled with water, in case of fire in the mill. Near the level of the perforated pipes in the third and fourth stories, the rising mains are carried through the wall and connect, on the inside, with the horizontal mains, which lie just below the floor beams, and close to the wall of the mill, and extend each way as far as the section of sprinkler extends, or about 70 feet. The horizontal mains diminish in size as they recede from the rising main. At intervals of about eight feet, corresponding to the bays of the mill, lines of perforated wrought iron pipes branch off from the horizontal main, first upwards, by short vertical pipes, equal in length to the depth of the beams, in order to reach the level of the ceiling between the beams; thence across the whole width of the mill, in the middle of each bay, the pipe being in contact with the boards forming the ceiling of the room. The diameters of the perforated pipes diminish as they recede from the horizontal main, being 1½ inches in diameter at the origin and ¾-inch in diameter at the other extremity. The perforations are one-tenth of an inch in diameter, 18 inches apart on each side of the pipe, making about 92 perforations in each line. These holes point a little above the horizontal, so that the jet of water will strike the ceiling a few inches from the pipe. The water issuing with considerable force, it will follow along the ceiling, falling in drops at short intervals, a portion of it reaching the beams, which are about 3½ feet distant, on each side of the perforated pipes.

In the upper story, the ceiling rises in the middle, corresponding to the pitch of the roof; the horizontal main is placed in the middle of the room, with the small pipes branching out on each side, and perforated the same as in the stories below.

The whole length of perforated pipe in the three stories of the mill is a little more than two miles, each section having about 1260 feet, containing about 1650 orifices. In one section, the total area of the orifices for the distribution of the water, is about 13 square inches; the sectional area of the rising main, is about 28 square inches; the proportion of sectional area in the rising main to the sum of the areas of all the orifices of distribution, being a little greater than two to one. In proportioning the diameters of the pipes throughout the whole system, substantially the same proportion is observed; thus, in the lines of perforated pipes across the mill, the sum of the areas of all the orifices of distribution is about 0·723 square inches; the sectional area of the pipe at its origin is 1·767 square inches, which is rather more than double the sum of the areas of the orifices of distribution. If the pipe at its origin had a diameter of 1·357 inches, its area would have just been double that of the sum of the orifices, but this is a size not usually manufactured. Of course there is no objection to the use of a pipe somewhat larger than the rule requires.

The pipes and perforations in each section of the sprinkler, are designed to discharge about 450 gallons of water per minute, which is about all that can be drawn from the main pipes in the mill yards from the reservoir alone, and maintain a sufficient working pressure; and of course, only one section at a time can be efficiently operated, unless the force pumps in that mill, or in some of the neighboring mills, are in operation.

The area of floor covered by one section of the sprinkler is about 10,300 square feet. The water discharged in one minute, would cover this area to the depth of about $\frac{1}{14}$ of an inch, which is at the rate of $4\frac{2}{7}$ inches per hour. The fall of water in a thunder shower is sometimes as great as this, but in this latitude it is very rare. There has been no opportunity as yet, to test the effect of any of the larger sprinklers, like that just described, in extinguishing a fire; many of the smaller sprinklers in the picking-rooms have however been used, and their operation has been in the highest degree satisfactory. There have been several opportunities for testing the larger sprinklers when there has been no fire; in every case, where the proportion between the sectional area of the pipes, and the area of the orifices of distribution which they supply, has been not less than two to one, the operation has been satisfactory, and in cases where sprinklers are in the lower stories, with short and well arranged supply pipes, they have operated satisfactorily, with a proprotion between supply pipe and orifices, of four to three. The proportion of two to one is, however, preferred. At Lowell the surface of the water in the reservoir is about one hundred feet above the top of the highest mill in the city. In order that sprinklers should operate with equal efficiency, with a less elevated reservoir, the proportion between the sectional areas of the supply pipes and the orifices of distribution should be proportionally greater. In cases where the reservoir is but little above the level of the top of the building, a proportion as large as four or six to one may be necessary.

The following table is computed for the proportion between the sectional area of the supply pipe and the sum of the areas of the orifices which it supplies with water, of two to one. For a proportion of four to one, the number of orifices which can be supplied is one-half that given in the table; for a proportion of six to one, the number is one-third that given in the table.

Diameter of supply pipe.	Number of orifices of distribution of different sizes which can be supplied.					
Inches.	$\frac{3}{16}$ inch.	$\frac{5}{32}$ inch.	$\frac{1}{8}$ inch.	$\frac{1}{10}$ inch.	$\frac{3}{32}$ inch.	$\frac{1}{16}$ inch.
8	908	1312	2048	3204	3644	8195
7	696	1004	1568	2452	2788	6274
6	511	738	1153	1802	2050	4610
5	355	513	800	1251	1424	3201
4½	287	415	648	1013	1152	2592
4	227	328	512	801	911	2049
3½	174	251	392	613	697	1568
3	128	185	288	450	513	1153
2½	89	128	200	313	356	800
2	57	82	128	200	228	512
1¾	43	63	98	153	174	392
1½	32	46	72	113	128	288
1¼	22	32	50	78	89	200
1	14	20	32	50	57	128
¾	8	12	18	28	32	72
½	3	5	8	12	14	32

Another Novelty in Cars and other Carriages.

From the London Artizan, Mar, 1865.

"A Patent Carriage Company, Limited," has been formed at Birmingham, for the purpose of bringing into use sundry novel improvements. The framework is of angle iron, welded. By using this several inches of space are saved, and added to the accommodation. The panels, which in ordinary cabs are of wood, in these new ones are of papier mâché. The paper resembles leather, but is stiffer and very tough. Every part of a cab usually of wood, indeed, is in this instance made of paper. The springs are beneath the body, which brings the wheels 5 inches nearer than in the ordinary vehicle, and yet also gives additional room in the width. The window runs along the roof on the inside, and draws down like a sash; and there is a sash door, which may be pushed down, and coils itself below the body of the vehicle. The ventilation is also improved. One style of Hansom has a top which slides down, and thus an open carriage is provided. The cost of vehicles is said to be considerably reduced by the new mode of construction.

For the Journal of the Franklin Institute.

On the Proportions of Cast Iron Steam or Water Pipes, with Faced Flange Joints. By Robert Briggs.

The proportions for cast iron pipes with faced flanges given by the following formulas and tables, have been reached after many years experience in their manufacture and use.

Those dimensions which are given by the first set of formulas (for 75 lbs. pressure) have been quite extensively adopted in the practice of engineers and machinists, the past eight or ten years. They give the minimum diameters to the flanges which will allow six sided nuts of proper diameters to be turned, and they give also such thickness to each flange, as has been found practically ample when the joint is faced all over, and either no packing or a very thin one over the whole joint surface is used. After the manufacture of many thousand of lengths, to these dimensions, no instance of failure to give tight joints or of breakage from unequal shrinking of the casting, or of breakage from want of strength is remembered. And the great excess of strength to withstand the internal pressure at which it is proposed to use them is made evident by the formulas. There has been found, however, a demand for flanged cast iron pipes to carry about 100 lbs. pressure, united with a requirement for flanges so large that the common square nuts (which have their inscribed diameters equal to twice that of the bolts on which they belong) can be readily turned on the back of the flanges, and also with a requirement for flanges so thick as to withstand the unfair strains occasioned by the use of packing rings made of yielding materials and placed within the diameters of the bolts as a substitute for surface packing.

It is of no avail to argue with those, who from false economy, purchase bolts and nuts by weight with little question as to quality, neither is it advisable to demonstrate the unworkmanlike character of the joints made by packing rings or the unmechanical procedure of making up lengths or getting small angles in this way. It is enough that flanges can be made sufficiently large and heavy to overcome these defects in construction and also sufficiently accurate to be used in the legitimate way. To meet these conditions the second set of formulas and tables have been made. It is not proposed at this time to enter into a discussion of the derivation or the character of the formulas. We will only say as regards the thickness, that on the smaller sizes, say below 12 inches diameter, the constant of thickness required for sound castings is very much in excess of that demanded to resist internal pressure and that the formulas establishing the number and size of bolts have been based on the assumption that for 75 lbs. pressure, four inch pipes require $5-\frac{9}{16}$ inch bolts, or for 100 lbs. pressure, the same size of pipes require $5-\frac{5}{8}$ inch bolts, and that for both 75 lbs. and 100 lbs. pressure, forty-eight inch pipes require $36-1\frac{1}{2}$ inch bolts. The results of this assumption as a whole system have been carefully investigated and found to give a value for the tensile strength of the wrought iron below the roots of the threads of the bolts, as compared with the tensile strength of the cast iron demanded to sustain internal longitudinal pressure, in the ratios of $2\frac{1}{2}$ to $3\frac{1}{2}$ times, the lesser ratio being on the larger bolts where the danger of overstraining by the workman in screwing up the bolts is the least.

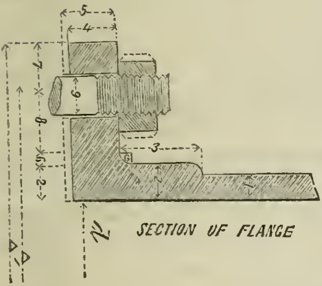
Formula for Thicknesses of Pipes, &c.

Let T = thickness of pipes in inches.
D = diameter of pipes "
d = diameter of bolt "
Δ = outside diameter of flange in ins.
Δ_1 = diameter of centre of bolt, "
K = tensile strength of cast iron.
c = co-efficient of safety above proof.
c_1 = co-efficient of proof above working pressure.
s = thickness necessary for sound castings for smallest pipe.
n = diameter of pipe which has such thickness that no addition for sound castings is required.
P = pressure per square inch in pounds.

The general equation of thickness then becomes,

$$T = \frac{P D c c_1}{2K} + s\left(1 - \frac{D}{n}\right)$$

Suppose $K = 18{,}000$ lbs per square inch,
$P = 75$ lbs.
$c = 3\frac{3}{4}$, $c_1 = 4$, $cc_1 = 15$.
$n = 48$ inches diameter.



SECTION OF FLANGE

which gives for seventy-five lbs. pressure and 15 times absolute strength, *without constant for sound castings*,

$$\therefore \quad T = 0{\cdot}02604\, D + 0{\cdot}25$$

suppose as before except that

$P = 100$ lbs., $c = 3{\cdot}28$, $c_1 = 4$, $cc_1 = 13{\cdot}125$,

which gives for 100 lbs. pressure and 13·125 times absolute strength, *without constant for sound castings*,

$$\therefore \quad T = 0{\cdot}0304\, D + 0{\cdot}292$$

Formula for the Flanges.

	75 lbs.	100 lbs.
1st. Thickness of pipe,	$T = 0{\cdot}026\, D + 0{\cdot}25''$	$= 0{\cdot}0304\, D + 0{\cdot}292''$
2d. Thickness of boss,	$= 0{\cdot}03\, D + 0{\cdot}31$	$= 0{\cdot}035\, D + 0{\cdot}44$
3d. Length of boss,	$= 0{\cdot}05\, D + 1{\cdot}10$	$= 0{\cdot}05\, D + 1{\cdot}10$
4th. Thickness of flange finished,	$= 0{\cdot}033\frac{1}{3}\, D + 0{\cdot}4$	$= 0{\cdot}04\, D + 0{\cdot}6$
5th. Thickness of flange in the rough,	$= 0{\cdot}036\frac{2}{3}\, D + 0{\cdot}45$	$= 0{\cdot}045\, D + 0{\cdot}86$
6th. Radius of hollow,	none given	$= 0{\cdot}008\, D + 0{\cdot}16$
7th. Centre of bolt to outside of flange,	$= 1{\cdot}1d + 0{\cdot}1$	$= 1{\cdot}25\, d + 0{\cdot}05$
8th. Centre of bolt to hollow at root of flange,	$= \left\{ \begin{matrix} 1{\cdot}04d + 0{\cdot}2 \\ \text{to root itself} \end{matrix} \right\}$	$= 1{\cdot}25\, d + 0{\cdot}1$
9th. diameter of holes in flange,	$= 1{\cdot}03\, d + 0{\cdot}03$	$= 103d + 0{\cdot}03$
Δ = outside diameter of flange,	$= 1{\cdot}06\, D + 4{\cdot}28d + 1{\cdot}22$	$= 1{\cdot}086D + 5d + 1{\cdot}50$
Δ_1 = diameter of centre of holes,	$= 1{\cdot}06\, D + 2{\cdot}08d + 1{\cdot}02$	$= 1{\cdot}086D + 2{\cdot}5d + 1{\cdot}40$
N = number of bolts,	$= 0{\cdot}7046\, D + 2{\cdot}182$	
d = diameter of bolts,	$= 1{\cdot}182 \sqrt{\frac{0.01785\Delta_1^2 + 0{\cdot}2052}{N}} + 0{\cdot}0492$ *	

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* The value of Δ_1 under the radical in this formula, is taken at an average computed one of $\Delta_1 = 1{\cdot}1043\, D + 2{\cdot}0127$

In the tables following the exact figures obtained for Δ, Δ_1, N, and d, by the formulas are not given but instead, the aliquot figures in inches or sixteenths nearest to fractional ones derived by computation.

There is besides the dimensions derived from the formulas, two columns giving the convenient lengths for each piece and the calculated weight of each length with the flanges in the rough.

Table of dimensions for Flanged Joint Cast Iron Pipes, intended to carry 75 lbs. per square inch working pressure.

Internal Diameter.	1st. Thickness of body.	2d. Thickness of boss.	3d. Length of boss.	4th. Thickness of flange finished.	5th. Thickness of flange in the rough.	6th. Radius of hollow.	9th. diameter of bolt hole.	Δ = outside diameter of flange.	Δ_1 = diameter of centres of bolts.	N = number of bolts.	d = diameter of bolts.	Length convenient to cast each piece.	Weight of each piece with flanges in the rough.
in.										No.	in.	ft.	lbs.
3	·328	·40	1·25	·50	·56		·55	$6\frac{1}{2}$	$5\frac{1}{4}$	4	$\frac{1}{2}$	8	94
$3\frac{1}{2}$	·341	·415	1·28	·511	·571		·61	$7\frac{1}{4}$	$5\frac{9}{10}$	4	$\frac{9}{16}$	8	113
4	·354	·43	1·30	·53	.593		·61	8	$6\frac{7}{16}$	5*	$\frac{9}{16}$	8	134
5	·380	·46	1·35	·56	·626		·61	9	$7\frac{1}{2}$	6	$\frac{9}{16}$	8	176
6	·406	·49	1·40	·60	·67		·68	$10\frac{1}{4}$	$8\frac{11}{16}$	6	$\frac{5}{8}$	9	250
8	·458	.55	1·50	·66	·736		·68	$12\frac{1}{2}$	$10\frac{8}{10}$	8	$\frac{5}{8}$	9	360
10	.510	·61	1·60	·73	·81		·81	15	$13\frac{3}{16}$	10	$\frac{3}{4}$	9	514
12	·563	·67	1·70	·80	·89		·93	$17\frac{3}{4}$	$15\frac{9}{16}$	10	$\frac{7}{8}$	9	685
16	·667	·79	1·90	·93	1·013		·93	22	$19\frac{8}{10}$	14	$\frac{7}{8}$	9	1110

Table of dimensions for Flanged Joint Cast Iron Pipes intended to carry 100 lbs. per square inch working pressure.

in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	No.	in.	ft.	lbs.
3	.3832	·545	1·25	·72	·8	·184	·61	$7\frac{1}{2}$	6	4	$\frac{9}{16}$	8	$118\frac{1}{2}$
$3\frac{1}{2}$	·3984	·563	1·28	·74	·82	·188	·61	8	$6\frac{1}{2}$	5†	$\frac{9}{16}$	8	139
4	·4136	·580	1·30	·76	·84	·192	·68	9	$7\frac{1}{4}$	5‡	$\frac{5}{8}$	8	166
5	·4440	·615	1·35	·80	·89	·200	·68	10	$8\frac{3}{8}$	6	$\frac{5}{8}$	8	217
6	·4744	·650	1·40	·84	·93	·208	·68	11	$9\frac{3}{8}$	6	$\frac{5}{8}$	9	303
8	·5352	·720	1·50	·92	1·02	·224	·68	$13\frac{1}{2}$	$11\frac{3}{4}$	8	$\frac{5}{8}$	9	451
10	·5960	·790	1·60	1·00	1·11	·240	·81	16	14	10	$\frac{3}{4}$	9	624
12	·6568	·860	1·70	1·08	1·20	·256	·93	19	$16\frac{3}{4}$	10	$\frac{7}{8}$	9	832
16	·7784	1·000	1·90	1·24	1·38	·288	·93	$23\frac{1}{2}$	21	14	$\frac{7}{8}$	9	1309

* 4 — $\frac{5}{8}$ bolts could be used for this joint in place of the tabular number and size, but the joint will be better if the number and dimensions given are followed.

† ‡ The $3\frac{1}{2}$ inch pipe flanges can have 4 — $\frac{5}{8}$ bolts and 4 inch can have 4 — $\frac{3}{4}$ bolts, but the joint will not be so well made as with the tabular numbers and diameters.

Puddling by Machinery.

From the London Builder, No. 1150.

Amongst the papers set down to be read at the annual meeting of the Institution of Mechanical Engineers in Birmingham, on the 26th ult., was one upon "machine puddling," by Mr. Menelaus. The author of the paper was accompanied by the manager of the Dowlais Company, who have the use of the patent. Mr. Menelaus had in the room a bloom of iron in the condition in which it left the furnace, and which weighed 5 cwt. As it lay upon the floor it looked like a hugh iron egg, and near to it were specimens of the same iron in a finished state. There were also diagrams, not only of the furnace in question, but also of the various descriptions of furnaces which contemplated the stirrings of the molten iron in the ordinary puddling furnace with a "rabble" or puddler's tool moved by machinery, so as to imitate manual labor. Mr. Menelaus said that he had thoroughly satisfied himself of the practical value of the invention; and the Dowlais Company were then engaged in laying down works, in which eight of those rotating furnaces could be kept in operation in the production of an unexceptionable quality of finished iron. The quality of the bloom and of the iron in the finished state, which had been rolled from other blooms made in the furnace, was pronounced excellent. Every such furnace as that now used at the Dowlais Works can easily produce 60 tons of iron a week. It is said that by the use of the rotary furnace the expense of production will be diminished, as compared with the cost of iron made by hand labor, at the same time that the quality is improved.

Thin Rolled Iron.

From the London Athenæum Jan., 1865.

A great feat has been lately performed. A sheet has been rolled from common iron at Messrs. Williams's iron mills, at West Bromwich, which is only the 1015th part on an inch in thickness. Another sheet, the 1400th part of an inch thick, has been produced by Messrs. Nevill, of Llanelly.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, March 16th, 1865.

The meeting was called to order with the President, Wm. Sellers, in the chair.

The minutes of the last meeting were read and approved.

The minutes of the Board of Managers were read and the names of the chairmen of the various standing committees were announced as follows:—

Committees.	*Chairmen.*
Library,	Pliny E. Chase.
Cabinet of Models,	John L. Perkins.
Cabinet of Minerals,	Coleman Sellers.
Cabinet of Arts and Manufactures,	John H. Cooper.
Meteorology,	James A. Kirkpatrick.
Exhibitions,	Bloomfield H. Moore.
Meetings,	Fairman Rogers.

The following donations to the Library were also reported, from the Royal Astronomical Society, the Royal Geographical Society, the Statistical Society, the Society of Arts, and the Institute of Actuaries, London; the Canadian Institute, Toronto, Canada; Hon. Wm. D. Kelley, U.S. Congress; Frederick Emmerick, Esq., Washington D.C.; Joel Giles, Esq., Dr. Thomas S. Kirkbride, and H. Morton, Philadelphia.

The Committee on the adoption of a standard for Weights, Measures, and Coinage of the United States reported progress.

The Committee on steam expansion reported that the time as yet devoted to the subject had been occupied in the arrangement and construction of apparatus and in the determination of certain constants which must play an important part in the calculations connected with the actual experiments.

The Committee on Screw Threads and Nuts reported that they had received letters from F. V. Rodman, Major of Ordnance, M. C. Meigs, Quarter-Master General, and from J. F. Holloway, Cleveland, Ohio, in general terms endorsing and approving of the report of the Committee.

On motion of Coleman Sellers, Esq., the report of said Committee after being read was finally adopted.

The Committee to draft a petition to Councils with reference to the appointment of an inspector for steam boilers, reported the draft of said petition, which being read, it was moved by Prof. Frazer, that the officers of the Institute be instructed to sign, seal, and cause to be presented, the aforesaid petition. This motion was carried.

Prof. Fairman Rogers then described the apparatus which had been prepared for the experiments on steam expansion, in effect, as follows:

Mr. Fairman Rogers.—If there is nothing else to occupy the attention of the meeting, I think that it would be interesting to the members to have some description of the essential portions of the apparatus used in the experiments on the expansion of steam now being made in New York.

I should the more like to describe it as we are anxious to have the opinions of persons interested, as to the method of experimenting which is employed.

It is known to the members generally, that the commission is appointed from the Franklin Institute, the National Academy of Sciences, and the Navy Department, the appointments being made by the authority of the Navy Department.

The object of the experiments is the determination of the relative economy of different degrees of expansion.

It will be remembered that Mr. Isherwood, Chief Engineer U. S. Navy, has for some time held the opinion, that *all practical questions being considered*, there is little or no advantage in the use of steam expansively in steam vessels. These views are the results of experiments made by him and under his direction, and are quite at variance with those held by engineers generally, and the difficulty has hitherto been that all such experiments were made with engines especially intended for some particular degree of expansion, and therefore not adapted to experiments for the comparison of the results of varying degrees.

The Navy Department desired therefore to have the experiment made with an engine built expressly for the purpose.

The apparatus was built by Mr. Allen of the Novelty Works, who, with Mr. Isherwood, at that time composed the commission. After the apparatus was set up, the joint commission was appointed.

The apparatus consists of a large engine which has a number of cylinders of different diameters and the same stroke (20 inches); the cubic capacities of the cylinders vary with their varying diameters and the valve gear is so arranged that they each receive the same amount of steam before cutting off, in other words, they each use the same quantity of steam at each stroke.

The engine is a vertical engine with a fly-wheel and accurately balanced, and the cylinders are changed by unbolting them from the bed plate which has the proper arrangements to receive the different sizes.

After the form of engine was decided upon, the work to be done or the kind of resistance to be provided was discussed.

A centrifugal pump raising a certain quantity of water in a given time was proposed and abandoned out of deference to the opinions of many engineers who were consulted. The friction dynamometer appeared still more objectionable in experiments that were to be carried on continuously for many hours at a time, and finally the plan of fans rotating in air was adopted.

Seventeen fans on a shaft, which is a prolongation of the engine-shaft were provided, each fan rotating in an air-tight chamber.

The fans are eleven feet in diameter, have eight arms, and vanes which are adjustable to the arms, and with the chambers are as much alike as it was possible to make them. The fan-shaft is cut between the fans so that by means of sleeve couplings any number may be run together.

If the full stroke cylinder with a certain pressure and a certain number of revolutions would run ten fans a certain number of revolutions, the work done by any other cylinder of the same pressure will be represented by the number of fans run by it.

Since, however, fractional fans or fans of reduced diameter might be necessary to furnish the exact amount of resistance, it is desirable to have some way of measuring the resistance thus produced, the more so, as it was predicted that the changes of barometric pressure and of temperature would have a very serious effect on the regularity of the running of the fans.

Mr. Allen therefore proposed a dynamometer which has been put in operation and to which I wish particularly to call your attention.

The shaft being cut between the engine and the first fan, a grooved pulley is keyed upon the engine shaft and one exactly similar upon the fan shaft. An endless rope is laid over these two pulleys in such a way that the bight of the rope hangs down before and behind. In these bights are hung two grooved pulleys of a diameter equal to the distance of the large pulleys apart, and to these smaller pulleys equal weights, so that the rope is held tightly in the grooves of the large pulleys. The engine pulley being turned by the engine, sufficient extra weight is added to the hanging pulley on the driving side of the rope to equal the strain on the rope which represents the resistance of the fans, when the whole system will be in equilibrium and the amount of power required to drive the fans will be measured by the tension of the rope, and consequently by half the extra weight which has been added.

If the resistance of the fans increases by any means, the weight rises; if the resistance diminishes, the weight falls, and a spring balance is fastened to the weight and to the floor to take up these irregularities.

A rod attached to the weight and carrying a pencil moving over the surface of a cylinder running from the shaft, serves to register the power required to run the fans.

By this apparatus the friction of the fan-shaft can be measured and any change in the resistance from varying density of the air is immediately indicated.

The experiments so far led to the belief that the changes from this cause will not be troublesome in amount.

It is found that the pencil rises and falls with each stroke of the engine, showing irregularities at different parts of the stroke, although the engine seemed to be well balanced.

Another wheel will be added to the train which runs the paper so that the curve will be more developed and the action of the engine may be more carefully studied.

The same result can be obtained by using four bevel wheels, but there might be some uncertainty as to the equal wear of these wheels.

At first it was supposed that the fans should run faster than the engine, and they were geared four to one, but the wheels were somewhat noisy, and showed signs of irregular wear which, it was feared, might affect the results. The wheels were therefore removed, and the fans run directly from the engine-shaft, their diameter being increased. Of course by taking off the dynamometer rope and coupling the shaft between the large pulleys, the fans can be run without the dynamometer.

Every precaution has been taken in regard to the oiling. Where there are so many journals this is of great importance, and it has been found best to give a very abundant supply of oil and to use the oil only for a short time as it seems to be injured by its exposure to the air.

There are many matters of detail, the consideration of which would detain us too long, but I will mention the arrangement used to keep the steam at a constant pressure in the cylinder. It was at first done by a man at the throttle, but that was not altogether satisfactory, and an arrangement devised by one of the assistant engineers was adopted.

The valve is opened or closed by a screw spindle which has a rather fine thread; on this spindle are two ratchet wheels with the teeth turned in opposite directions; over these wheels are two palls or clicks which receive a constant reciprocating motion from the engine.

The mercury column representing the pressure, rises and falls in a glass tube in which pointed wires are arranged in such a manner that when the mercury rises above the desired point, a galvanic circuit is closed, an electro-magnet is formed, and one of the palls is drawn down into contact with one of the ratchet wheels which it works, thus closing the throttle.

Upon the mercury receding the pall is disengaged and the valve remains steady.

If the mercury falls too low and the circuit is broken, a spring brings the other pall into contact with its wheel and the throttle is opened until the proper pressure is restored. This regulator gives great satisfaction, the only difficulty being that the mercury (or some impurities in it) sometimes adheres in threads to the platinum points.

Prof. Vanderweyde.—What results have been arrived at as to the economy of expansion?

Mr. Rogers.—Up to this time the experiments have all been directed towards perfecting the apparatus, determining the friction, &c. It is not yet considered to be in a state to permit the regular experiments being undertaken, but it is nearly perfected.

Mr. Coleman Sellers.—I would ask if the irregularities referred to in the register of the dynamometer might not be due to the elasticity of the cord which passes over the pulleys. May this not stretch and contract at different parts of its length?

Mr. Rogers.—It is possible; but the variations appear to coincide with the revolutions of the engine. The more expanded curve will show this more clearly.

The cord is made of raw-hide twisted and wormed with spun yarn, soaked in oil and well rosined. Some trouble was occasioned by the oil coming out of the rope for ten days or more after it was put up and by the stretching of the rope.

Mr. Shaw.—I made and used, some ten years ago, a dynamometer somewhat upon the same principle, which worked remarkably well.

It consisted of a pulley loose upon the shaft which was to be worked. The belt from the engine ran on the face of the pulley and a cord from one arm of the pulley drew the shaft round by a radial arm fixed to the shaft. To enable me to measure the tension of this cord it was passed through a pulley at the end of the radial arm and down to a sliding sleeve on the shaft which was drawn outwards by a weight or a spring. This sliding sleeve may in fact be done away with, and a swivel in the cord used. This is not effected by the stretching of the cord.

Mr. Rogers.—That form is new to me, although I have seen a description of something nearly like it.

The President, Mr. Wm. Sellers.—I think that one of the difficulties with the dynamometer described by Prof. Rogers, would be the varying friction of the shafts owing to the varying load on the cord, for different amounts of work to be measured.

As you increase the work you must increase the excess of weight which measures it and you thereby produce a change in the friction which it will be difficult to calculate.

Mr. Rogers.—The load which forces the cord into the grooves of the pulleys is a constant one, and it is only the excess of weight on the driving side which changes, and the friction on the shaft is part of the resistance which is measured by the dynamometer.

Mr. Wm. Sellers.—It would be upon the engine-shaft also.

Mr. Rogers.—Yes, that is one of the difficulties, and we propose to determine these resistances in the engine by special experiment; but I do not see how any dynamometer could be arranged which would not be liable to the same objection.

Mr. Wm. Sellers.—The friction caused by the pressure necessary to cause the cord to take hold in the grooves, is greater than that which would occur with gearing.

Mr. Rogers.—There is no doubt that the friction with gearing is much less than with the pulley or with any kind of cord, but it is doubtful whether the gearing would keep in good condition or whether it would not be liable to some changes which we could not readily detect.

Prof. Frazer.—The irregular working of the first gearing shows that there must have been some resistance of which you are not aware.

Mr. Rogers.—When you have command of the size of the gearing, and where the four wheels could be exactly of the same size, I do not think that the irregularity of wear could be a serious matter.

Prof. Frazer.—You do not mean that the pressure on the journals would vary during the experiment; only that it would be greater when the dynamometer was on, than when it was off.

Mr. Rogers.—During the series it would vary with increased power in the engine; increased weight would be required to produce tension enough in the cord to transmit the power.

Mr. Wm. Sellers.—The difficulty would be to compare one experiment with the other.

Mr. Rogers.—It is proposed to determine these differences as nearly as possible and it can hardly be difficult to measure the friction with the data which we have.

President.—If there are no other remarks, the report from the Secretary would be in order.

Mr. Thomas Shaw.—I would like to make some observations upon engine counters; as they are at present, they are liable to get out of order; I have an arrangement operated by a crank which is not liable to that objection. I propose to connect directly with the crank; I connect with a vibrating rod or elastic pitman; the difficulty in the employment of the crank is the dead point. I propose to get over these points by means of a spring fixed at right angles to the line of motion. This rod might be constructed so as to compensate for the action of heat and cold; the slightest alteration of the rods alters the engine counter and prevents it from operating.

President.—The Secretary's report is now in order.

SECRETARY'S REPORT.

The Secretary then read his report on new discoveries and inventions, as follows:

Mechanics.—Under this head we have first to notice a paper read before the Mechanical Engineers' Society of London, in which is given a very full description of several *traversing cranes* recently erected in the Locomotive Works of the London & N. W. R. R. at Crewe. These cranes, of which seven are now in use, have been working in a satisfactory manner, some of them for as long as three years. Motion is communicated to them by a light cotton cord running the whole length of the shop traversed by the crane, and driven at the rate of sixty miles per hour, its force being taken up as required at the different points by friction disks and pulleys. It is also stated that the cords employed do not wear out as rapidly as might be expected, but last on the average as much as 10 months each. They pass, in turning, over very large pulleys and are elsewhere supported in smoothly polished shoes of iron or glass.

We should remark with regard to these cranes, that their usefulness, though unquestionable, is mainly confined to such business as that of the locomotive shop, as in other establishments the necessity of a *successive* use of the apparatus by different parties of workmen, would entail an injurious loss of time.

Much has also been written in various English journals on the subject of a pneumatic machine for weaving, whose chief points of originality consists in the movement of the shuttle, which is blown back and forth by a blast of air, thus, as it is claimed, obviating the friction, heating and consequent injurious effluvia of charred oil, as well as the danger of greasing the fabric.

A gas engine, *i. e.*, one in which motion is produced by explosion of burning gas mixed with air, claims much attention from the French and English journals. This apparatus is patented by a M. Lenoir, and if as efficient as it is represented to be, will possess value as an easily arranged generator of moderate force, not bulky and capable of use and discontinuance without loss of time or fuel in preparation. Though the steam engine at present fears no rival as an economical force developer on the grand scale, there are many objects to which some small but *convenient* prime motor might be very advantageously applied, even though in economical utilization of the force implied, in its fuel it were greatly inferior to the above.

We have also to notice an improved form of chair for joining rails patented by R. H. Lamborn, of this city. This consists of a rectangular trough or gutter of wrought iron, in which the ends of the rails to be united are set, being kept in place by a yoke or staple of iron, passed through the neck of each rail near its end, and fastened by a split key, driven through the ends of the yokes below the trough. The apparatus consists of but five parts, the trough, two yokes and two keys, all of the simplest construction. This chair has been tried on the Penna. Cent. R. R. near Altoona, with such success that ten miles of track are being laid with it by this company, and very strong endorsement has been given to the plan by eminent engineers.

There has also been presented an improved balanced rotating steam valve by Arthur Irvine, of Philadelphia. This consists of a three port rotating cylindrical valve, balanced by the exposure of a part of the cylinder through a properly arranged packing-box at the side opposite to the exhaust port. A hood may also be attached over this opening in low pressure engines and connected with the condenser.

We have also to notice an oiler or cast iron oil can for lubricating machinery in motion, by Richard Dudgeon, of New York, the inventor of the hydraulic jack. The body of this can is cast in one piece, and has a plunger (inserted through a proper packing), which, being forced in by a motion of the thumb, drives out a jet of oil from the nozzle of the can.

Physics.—Light. A substitute for the yellow glass used by photographers to intercept actinic rays has been suggested by W. Sidney Gibbons of Melbourn. This is a mixture of gelatine and bichromate of potash spread as a varnish over thin cotton cloth or similar material. The same material mixed with lampblack is also said to form an excellent paint for a black-board, as it becomes after exposure to light very tough, and is unaffected by washing.

A very interesting memoir by Dr. Tyndall, on the invisible heat rays accompanying light has been read before.

In this paper are described experiments made with a spectroscope entirely constructed lenses, prisms, &c., of rock salt, and with very dark solutions of iodine in bisulphide of carbon, by which the light rays may be entirely arrested while those of heat pass freely. By these means it was possible in a perfectly dark room, to focul upon a certain point the rays from an electric lamp so that intense heat was developed in this spot without, however, the least appearance of light. The experimenter also daringly placed his eye in this heat focus, and though the lid was scorched when unprotected, yet when this was guarded against, no sensation was produced by the passage of the heat rays into the pupil, owing, no doubt, to the fact that they were absorbed by the aqueous humors of the eye lenses.

A megascope or magic lantern for opaque pictures illuminated by the lime-light has been patented by a Mr. Chadburn, optician, of Liverpool. This is, however, a very old instrument revived, rather than a new invention, and of interest only because our present great facilities for producing intense light enable us to use such apparatus with ease and good effect.

We have also another modification of the same apparatus in the Photographiscope Catoptric Lantern patented by Geo. Sibbald, of Phila. The light is here obtained from two coal oil lamps, and from its ease of management may be of great value to artists and manufacturers of decorative articles, enabling the first to produce readily, an enlarged and accurate outline from a small photograph or the like ; and the last to see the effect of any design, with all its colors, &c., enlarged to any desired extent. (This instrument was then exhibited in operation.)

Electricity. An application of secondary or induced currents to telegraphic purposes is found in a patent granted to I. B. Thompson, London. The plan of apparatus here proposed seems simple and well arranged and the idea embodied a very good one. Intense batteries, implying in practice the use of nitric acid are troublesome and expensive to maintain ; while intense currents must yet be had to work long lines. Any means, therefore, by which a low intensity battery almost self-regulating like that of Smee, can be made to furnish the requisite intense force without increase to the number, but only to the size of its elements, is a great and valuable acquisition.

We see, also, a proposed plan for pointing pins and needles, without such injury to the health of the workmen as attends the present grinding process, invented by a M. Cauderay, of Paris. The wires to be sharpened are attached to the positive pole of a battery, and then plunged in acidulated water, connected by a plate of metal, with the negative pole. They then quickly become pointed, even with a feeble current, as is asserted.

Chemistry.—The so-called passive state of metals has been proved by Dr. Heldt, to result from the formation of an insoluble film differing in different cases, but always protecting the metal from the attack of the acid or other solvent.—*Les Mondes*, vol. vi., page 413.

Richt and Richter have obtained enough of their new element, indium, to determine its physical properties. It is a white metal, soft, ductile, not easily tarnished, melts at about the same point as lead, gives a blue color to flame when combined with chlorine or sulphur. Its specific gravity is 7·277, and equivalent 37·07, that of hydrogen being 1.

Cæsium has been found by M. Pisani to form 34 per cent. of the mineral Pollux, in Elba.

Tellurium has been found in an ore of bismuth on the mountain Illampu in Bolivia.

Iodine has been found in Chili as an iodide of lead associated with PbO and PbCl.

St. Caire Deville has published some very curious experiments, from which it would appear that at a very high temperature the firmest chemical compounds were decomposed.—*Comptes Rendus*, vol. lix, page 873.

An ingenious process for ornamenting glass is embodied in a paper read by Mr. Kuhlman, before the Academy of Sciences.

Glass plates are coated with solutions of sulphate of zinc, or of magnesia thickened with gum water. This material soon crystallizes in very beautiful arborescent figures which may be then etched into the glass by the use of hydrofluoric acid, and afterwards colored by the fusion of substances which may have been mixed as fine powders with the gum-water, &c., first mentioned, or the glass may be silvered, which gives a very pretty effect.

The theory of steel has been the subject of fresh discussion and the "carbon hypothesis" ably supported by William Baker and Graham Stuart, from experiments made by them with many specimens of the best kinds of iron ; also by M. Margueritte before the Paris Academy of Sciences.

After the conclusion of the report, the meeting was, on motion, adjourned. HENRY MORTON, *Secretary.*

A Comparison of some of the Meteorological Phenomena of MARCH, 1865, *with those of* MARCH, 1864, *and of the same month for* FOURTEEN *years, at Phila., Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	March, 1865.	March, 1864.	March, for 14 years.
Thermometer—Highest—degree,	76·00°	59·00°	78·50°
“ date,	21st.	13th.	3d, 1861.
Warmest day—Mean,	64·50	48·50	66·00
“ “ date,	16th.	13th.	3d, 1861.
Lowest—degree,	24·00	20·00	4·00
“ date,	11th.	22d.	10th, 1856.
Coldest day—Mean,	31·67	27·33	11·50
“ “ date,	11th.	22d.	16th, 1856.
Mean daily oscillation,	13·97	13·55	14·72
“ “ range,	6·72	5·11	6·13
Means at 7 A. M.,	42·03	34·35	35·87
“ 2 P. M.,	52·40	45·07	46·96
“ 9 P. M.,	46·16	39·03	40·53
“ for the month,	46·86	39·48	41·12
Barometer—Highest—Inches,	30·210 in.	30·131 in.	30·522 in.
“ date,	1st.	3d.	3d, 1852.
Greatest mean daily press.	30·148	30·090	30·445
“ date,	1st.	3d.	11th, 1852.
Lowest—Inches,	29·185	29·184	29·158
“ date,	22d.	30th.	17th, 1854.
Least mean daily press.,	29·241	29·246	29·241
“ date,	22d.	30th.	22d, 1865.
Mean daily range,	0·188	0·176	0·193
Means at 7 A. M.,	29·825	29·723	29·840
“ 2 P. M.,	29·777	29·656	29·783
“ 9 P. M.,	29·826	29·699	29·821
“ for the month,	29·809	29·693	29·815
Force of Vapor—Greatest—Inches,	0·507 in.	0·361 in.	0·549 in.
“ date,	16th.	5th.	18th, 1859.
Least—Inches,	·076	·064	·023
“ date,	6th.	20th.	5th, 1858.
Means at 7 A. M.,	·208	·146	·165
“ 2 P. M.,	·227	·149	·179
“ 9 P. M.,	·227	·160	·181
“ for the month,	·221	·152	·175
Relative Humidity—Greatest—per ct.	96 per ct.	95 per ct.	100 per ct.
“ date,	9th. & 31st.	31st.	often.
Least—per ct.,	24·0	18·0	16·0
“ date,	18th.	9th.	31st, 1860.
Means at 7 A. M.,	72·6	71·5	73·4
“ 2 P. M.,	53·8	50·4	53·0
“ 9 P. M.,	67·1	65·8	67·7
for the month,	64·5	62·6	64·7
Clouds—Number of clear days,*	7	10	9·7
“ cloudy days,	24	21	21·3
Means of sky cov'd at 7 A. M.	62·6 per ct.	61·0 per ct.	60·1 per ct.
“ “ “ 2 P. M.	71·9	63·5	61·9
“ “ “ 9 P. M.	58·1	50·3	46·2
“ “ for the month,	64·2	58·3	56·1
Rain and melted Snow—Amount,	4·875 in.	5·243 in.	3·357 in.
No. of days on which Rain or Snow fell,	13·	10·	10·9
Prevailing Winds—Times in 1000,	S58°40′W ·154	N.46°7′ W.221	N71°10′W·280

*Sky, one-third or less covered at the hours of observation.

JOURNAL

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FOR THE

PROMOTION OF THE MECHANIC ARTS.

MAY, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Papers on Hydraulic Engineering. By Samuel McElroy, C. E.

No. 6.—*Fire Service and Hydrants.*

(Continued from page 245.)

Hydrant Improvements.—The following abstract of the patents which have been issued from 1850 to 1864, is given to illustrate the direction which improvements have taken, over the original form described. The hydrants not intended for fire-service have been noted as “drinking” hydrants, as belonging to a different class, but serve to present the same general idea of progress.

Abstract of Hydrant Patents, 1850 *to* 1864.

Date.	Inventor.	Characteristics.
1850.		No issue.
1851.		“
1852.		“
1853. Dec. 13.	Jas. Cochrane.	Drinking hydrant; elastic chamber for ventage of charge.
1854. Aug. 22.	C. M. Alberger.	Hose hydrant, hitching-post, and street washer, with two-way cock.
June 6.	N. W. Speers.	Hydrant cap.
1855.		No issue.
1856. Nov. 11.	Robert Lawson.	Device for ventage.
May 27.	C. K. Landis.	Pump hydrant; application of steam, with float, slide valve, and double valve.
“ 6.	C. J. Cowperthwaite.	Drinking; protecting case and nozzle, handle and slide valve.
April 22.	John Culver.	Device for ventage.
“ 8.	E. J. Baker.	“ “
“ 1.	Henry English.	Supply through slotted ports, with square shanked valve.
Jan. 15.	C. J. Cowperthwaite,	Drinking; supplemental valve for disconnection, hand lever, and elastic cap.
1857. Nov. 10.	Lucien Moss.	Gas-pipe and burner within case, to thaw or prevent freezing.
June 23.	G. P. Perrine and J. E. Boyle.	Drinking; hollow piston-rod and nozzle, operated by lever and water head.

Date.	Inventor.	Characteristics.
1857. June 16.	Joel Bryant.	Drinking; supply and discharge ports with double cylinder, operated by rotating handle.
“ 9.	W. Bramwell.	Outer case, seat and washer, for disconnection.
“ 2.	W. W. Binny.	Drinking; worked by lever and spring valve.
April 21.	A. Hoagland.	Piston operated by crank-arm; ventage by special lifting valved piston.
Feb. 3.	W. Fields & S. Gerhard.	Drinking; pumps by combined plungers and lever.
Jan. 20.	Jas. G. Morgan.	“ air chambers and cistern for ventage.
1858. Dec. 21.	S. P. Francisco and W. P. Dickinson,	Piston for ventage, by compressed air.
Oct. 19.	James Swan.	Elastic and metal tube for ventage.
Aug. 31.	James R. Higgs.	Disconnecting valve case, with three valves and one supplemental valve and automatic vent valve and rod.
Mar. 2.	John Parham.	Arrangement of vent, and drops main valve below the supply branch.
“ 2.	James Powell.	Drinking; double-chambered cylinder, two plungers, and ports, operated by cam and arm.
Feb. 9.	K. Goddard.	Drinking; upper and lower case; spring valve, operated by plunger and weighted handle.
Jan. 26.	W. Race and S. R. C. Matthews.	Internal case, with annular and supplemental valve for disconnection.
“ 5.	Richard De Charms.	Drinking; improved three-way cock, with two air chambers.
“ 5.	John Hyde.	Application of syphon tube for ventage.
1859. Nov. 1.	W. James.	Drinking; movable cylinder and fixed piston.
Oct. 18.	J. H. Carter.	“ filtering application.
“ 4.	C. L. Stacy.	Side valve chest, with cup disks and vent improvement.
“ 4.	N. B. Marsh.	Drinking; double plungers, with perforated cylinders.
June 7.	J. Fay.	“ ball valve and rod, with supplemental spring valve to prevent waste.
April 19.	W. Race and S. R. C. Matthews.	Drinking; internal supply tube, cap spring and closed seat.
“ 5.	J. Bryant.	Annular tube through main valve and stem, with perforated vent top.
Feb. 15.	F. H. Bartholomew.	Supplemental ball valve and joint for disconnecting, with waste chamber and plug.
1860. Sep. 4.	Albert Fuller.	Combined cylinder and case for disconnecting, motion optional for vent valve and rod.
June 12.	Alfred Johnson.	Drinking; diaphragm and spring valve to prevent waste.
Jan. 24.	G. W. Robertson.	“ upper and lower chambers, non-conductor packing in upper.
1861. Sep. 10.	D. C. Cregier.	Supplemental disk valve, with valve trunk, for disconnection.
“ 10.	G. H. Rogers.	Drinking; guide tube, flanged ring and conical plug, with spring induction valve.
“ 3.	L. P. Black.	Pump or hydrant; earthenware plunger and rubber packing.
Aug. 20.	B. F. Moore.	Main valve seat, with thimble, band, and valve on main rod.
“ 13.	G. M. Selden.	Independent valves, worked by sliding valve spindle.
May 14.	Joseph Neumann,	Drinking; case and joint above main valve to prevent action of sand, &c.
Feb. 19.	John P. Kenyon.	Plunger and spout tube, for usual valve and seat.
1862. Oct. 14.	Samuel McElroy.	Valve and seat on supply branch, operated externally, with open-hydrant tube.
June 10.	J. Gibson and M. Herberger.	Drinking; elbow, screw-shanked cork, annular gasket, scutcheon and clamp nut.
“ 10.	G. J. and H. W. Ross.	Drinking; rotary eduction pipe and spring, connected with plug in supply branch.
May 13.	S. H. Brown.	Inclined planes, slide valve, and double-armed lever.
1863. June 9.	J. Regester.	Combined street and house supply cocks and metal casing.
May 26.	John G. Murdock.	Wasting open-mouth barrel, nozzle, valve, gaskets, and ventages.
Mar. 3.	John McClelland.	Sliding valve with slotted arm and crank motion.
Jan. 20.	Richard Stileman.	Sluice valve and casing to hydrant stem.

It will be observed that a number of patents refer to frost vents and frost prevention, one being for the use of gas jets within the hydrant cases; the remainder refer chiefly to methods of disconnecting the hydrant tube, without shutting off the water from the service main with which the branch connects, by the use of supplemental valves brought into action for this purpose; one covers the use of a tube free from the internal valve rod and the elevated valve seat.

The vent arrangement cannot be better simplified than in the Philadelphia, or some similar methods of positive motion, or the automatic tube, and the elaborate substitutes are not likely to be generally adopted.

The arrangement for disconnecting may be described, in principle, by reference to Mr. Cregier's hydrant which is simple in character, for its purpose, as adopted to a stand-pipe head.

This head is made with a movable top secured by bolts; its removal permits the detachment of a guide pin to the ordinary valve motion, so that the motion of the rod becomes rotary, and thus operates a screw shaft and supplemental valve fitted on the rod below the line of the hydrant branch; this valve rises to a seat adapted to it, just above the branch, which it thus shuts off from the tube, and the tube being jointed above this seat can be lifted out.

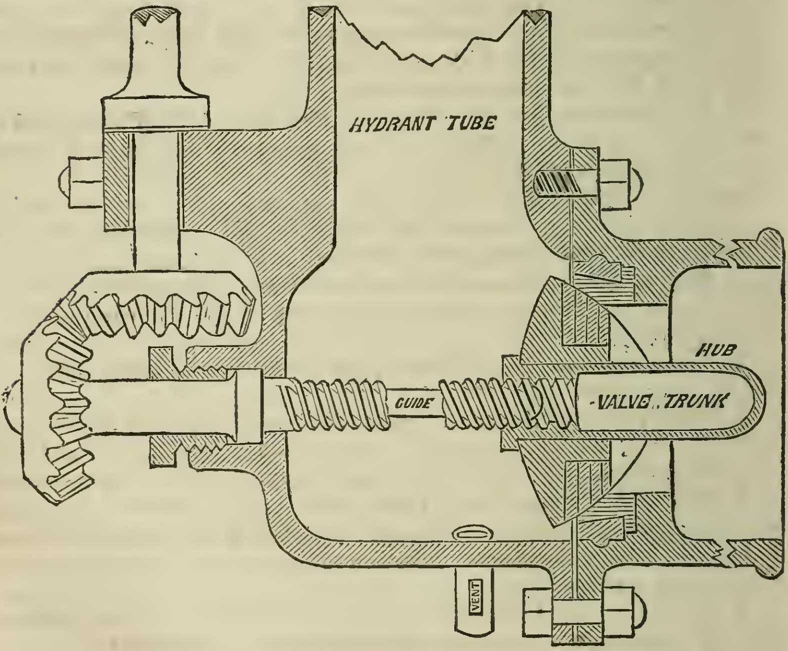
This involves the use of a second valve seat, with a composition valve, valve-shaft, and trunk, and rod extension, as all these parts must be protected from decay.

The advantage claimed for these disconnecting devices is an avoidance of the use of the service stop-cocks on the special line of main to which the hydrant is attached, which cuts off the house supply while the removal and replacement takes place. With hydrant bends leaded in, the time of melting, is, of course, much longer than where face joints are made, but in any case the occasions of removal are not frequent, and they can be made at a time of day when house service is nearly suspended. Boston, with 1451 hydrants in 1861, replaced 70; at this rate the term of service is about 20 years average in position, an average which does not warrant any expensive or complicated addition to the hydrant itself. Of 1220 hydrants in Brooklyn in 1863, 39 required removal, giving a much longer average of service. It is doubtful, therefore, whether the range of invention has apprehended the correct line of improvement in these appurtenances.

It is somewhat singular, also, that no importance seems to have been given to the use of tubes of enlarged calibre, or with greater freedom of discharge, with one exception, the precise size of hose-butt, apparently, having controlled this matter.

The arrangement, previously noticed as having been introduced in Brooklyn and in one or two cases in New York, and known as the *Lowry Hydrant*, has superior advantages in the discharge calibre of its tube. This is a "flush hydrant," and used generally at intersections of street mains. A puppet valve and seat is placed on the top of the main, by suitable connexions, the valve being worked by a rod in the usual way; the head of the tube is fitted, when in use, with a screw cover, carrying four or more hose nozzles; according to Brooklyn practice, this cap is removed when a fire is over and stored in some selected, adjacent place, and a heavy cast iron cover substituted for ordinary street wear.

The effect of this arrangement is to increase the hydrant discharge and to concentrate several hose lines at one point. If the fire is near the hydrant much hose friction is saved; but if distant this friction is increased. Compound nozzles are also open to the objection, in experience, that the hose which is first attached, must be shut off, to admit a second, and so with the third and fourth, and much contention results between the firemen; it is also objectionable to have part of a hydrant apparatus stored away from it, involving delays and difficulties in finding and attaching it; if placed at street intersections, in many cases the intervals must be great between such hydrants and the hose service thereby embarrassed; while their expense has hitherto restricted their adoption.



In view of the foregoing experiences, the *open-throat hydrant*, which is illustrated as to its valve motion on the opposite page, was designed in order to meet and remedy valid objections to existing arrangements.

As will be observed, this device consists of a vertical tube which can be adapted to any form of head, connected by a face joint with a hub which carries the valve seat, and receives the branch main, or can be so formed as to make a T-branch of the street main. This dispenses with the usual bend and its parts, and brings the valve, the seat, and the vent down to the branch main level, and consequently below frost.

The motion is external, by a simple bevel geer, which is cased in, within the hydrant case and is readily accessible.

An improvement is also suggested, in making the hydrant tube with a slight upward flare, so that in case of ice-formation within it, at any point above the valve chamber, the first water pressure from the opened valve, would free the ice-cylinder, so as to permit an active thawing current out of the nozzle. Another improvement is suggested as to the nozzle, which is made with a compound form, so that unscrewing the outer hose-cap will give the usual size nozzle and unscrewing the outer nozzle itself will give a full size opening of four inches and upwards, for the steamer suction pipe.

The advantages secured by this design may be thus summed up:—

1. It is not restricted to location at main pipe intersections, although it may easily be adapted to any calibre of main, and to use as a "flush" hydrant with several nozzles.
2. It secures, without much increase of cost, twice the usual area of hydrant tube free from all working parts and an important increase of head on hose or engine connexions.
3. It provides a hydrant nozzle, of four inches or two and a quarter at will, so that "steamers" may use the larger without loss of power by suction as now required, and is easily adapted to either "flush" or "stand-pipe" head.
4. Its automatic vent is placed below the valve seat and frees the hydrant lower than the hydrant branch.
5. The hydrant tube and valve motion may be removed and replaced without melting or making lead joints, or disturbing any part of the hydrant branch.
6. The workmanship of the valve and seat may be made more perfectly, from easier access.
7. The valve-trunk can be thrown back and the valve chamber enlarged to any desirable extent to secure ample water way, and any desirable amount of power or speed may be given to the valve motion.
8. The valve motion being much deeper, is not choked by ice, in case the hydrant tube is frozen above it, hydrant branches not being liable to freeze, and the tube may therefore be readily thawed when the valve is opened.
9. The valve and valve-seat cannot be obstructed by lodgement of sand or gravel, and the screw shaft is protected from injury.
10. The valve seat hub may be made of any form desired for permanent attachment to the hydrant branch.

In the drawing the valve chamber is represented as a hollow cylinder, but in practice it would be better as a globe.

Summary.—The foregoing discussion of the *office* and *methods of distribution systems*, *progress of fire engines*, *conditions of fire service*, and *defects of distribution*, illustrates, in the facts and principles presented, the need of the most careful and liberal attention to the details of water supply, so as to conserve and realize their legitimate office.

We have it presented as a leading principle, that the cost of water supply and the annual expenses of administration, are largely exceeded in scale, by the universal and disastrous losses by fire. It is strange that people so practical as we are, so prompt to remedy and prevent evils which occur to property and contingencies which threaten investments, should overlook the importance of the argument on this point, which presents itself in nearly every successive daily paper, and swells into an overwhelming annual aggregate; it is so, nevertheless. Water supply is generally dealt with as a luxury, with which the age of gold, rather than of brass or iron, is more particularly concerned, and the engineer must "make friends with the mammon of unrighteousness" and be able to demonstrate comforting incomes, before his plans can be adopted, or looked upon with favor. Here, in Brooklyn, with a confirmed position in population and wealth, it still required not less than five years of patient and continuous effort to carry the measure, which was twice voted down by the citizens; but the person who would suggest a public election on the question of abandoning the supply, would not be a very popular man now. In all matters of this kind, a few men are always ahead of their age, and are generally unrewarded when they succeed, except, perhaps, in the consciousness of a public sanitary achievement.

We also observe the necessity of keeping the details of supply, as progressive as the appliances of fire service. The introduction of steam fire engines is destined before long, to work a radical change in all the systems of fire protection, as to the paid department of workmen, the methods of application, and the systems of insurance; and our water supplies must be adapted to such changes in method, as a sequence, which ought, in fact, to have been an anticipation.

With regard to the improvement of distribution service mains in calibre and arrangement, which have been discussed and are abundantly justified by the details of experience presented, it need only to be said that this is requisite for all domestic uses, as well as fire service. It is to be hoped, that the day is not far distant, when by common consent, the present practice of niggardly restriction in service outlay, will be abandoned for the true economy of wise expenditure in adequate mains at the outset, and a careful avoidance of annually accruing evils, which "he who runs may read." This is a most important condition of improvement.

In the same scale of correct practice we may certainly include the improvements suggested in hydrants, as to their intervals of position, their details of construction, their sewer drainage, and their use, under a more carefully subdivided system of fire service. A general reconstruction of this kind may seem formidable at first sight, but it does not merit any special apprehension as to cost, or trouble in adoption. It belongs to that order of improvement, which we might term "stratified," since it is but a step or two gained, in a system of progress; which the demands of the age make imperative and the sources of economy, in losses prevented, most amply justify.

The whole discussion of this subject belongs to that class of questions, which it is difficult to exhaust or fully present in their attendant arguments and we can only indicate, at present, the general course of examination, with the hope that others may assist in its proper conclusion.

Method of Building under Water. By JOHN MOFFAT, C. E.

From the Lond. Civ. Eng. and Arch. Journal, Mar., 1865.

[Read at the Institution of Engineers, in Scotland.]

Quay walls are the principal objects of subaqueous construction; and these have hitherto been made of wooden or iron framing, or of stone or brick masonry. In the former case they depend for their stability chiefly on the strength given by cohesion, and in the latter on that afforded by their weight. The security and durability of masonry, as compared with any description of framing, in every kind of harbor construction, are so great, that it would be invariably adopted, were it not for the consideration of time and expense. A pier can always be made of wood or iron much quicker and cheaper than of stone; and on this account they are frequently resorted to in cases where the time or the money at the disposal of the engineer render the superior structure unattainable.

About ten years ago I had an extension of the outer quay and breakwater at Ardrossan Harbor to execute, which had to be completed in one summer, and for a limited sum. All the works at that harbor have hitherto been executed in stone, except a small pier of timber, which, though cheap at first, turned out in the long run to be the dearest work we had, on account of its being destroyed by the *Teredo navalis* in about ten years. We had also found that cast iron is corroded so rapidly, as to render an iron structure nearly as objectionable as a wooden one. And I was thus induced to turn my attention, to devising a plan for executing the building in masonry, within the limits assigned to me. And I succeeded in doing so, by the plan which I shall now proceed to describe.

In a stone pier, the portion which consumes most time and money, is that under low water. Hitherto this portion has been built in separate masses in wooden caissons, and floated to its position when completed, the sides of the caisson being disengaged when the mass of masonry had been set. Or it has been formed entirely of large squared ashlar, dropped into its place by means of water lewis, or set by means of the diving bell. At Ardrossan the masonry under water has been built entirely of ashlar, set partly in the first way, and partly in the second. Where set by the water lewis, the stones are laid so that the beds are not horizontal, but at an angle of 45°. After the first row of stones has been laid, and which must be done with very great care, the remainder are lowered so as to catch the upper edge of the inclined bed, and are slipped along it until they reach their position, when the lewis is disengaged in the usual way. Where set by the diving bell, the courses are horizontal, and form a solid mass of ashlar of the ordinary construction.

I found by calculation that with the plant at my command, I could not complete the extension, by either of these methods, in less than two seasons, and that the cost would exceed the sum at my disposal. It then occurred to me, that I could attain my end by forming the masonry under low water of large hollow masses of brickwork, constructed in the graving dock, and floated to their position in the quay, after reaching which they could be filled with concrete. And on trial I found that this plan could be easily carried out, and furnished a method of submarine masonry much cheaper and quicker than any I had yet tried.

The average depth at low water was nearly 20 feet; and I leveled out the foundation, and laid three courses of ashlar with the diving bell in the usual way, so that the upper bed was about 15 feet from low water. The hollow brick masses were made 15 feet long, 15 feet deep, and 11 feet thick. The bottoms were of cast iron plates $\frac{3}{4}$-inch thick, strengthened with projecting feathers along the edges. The walls were 20 inches thick, formed of large bricks 20 inches long, 10 inches broad, and 5 inches thick, set in Roman cement, and strengthened by horizontal strips of hoop-iron laid along the courses. When finished they were nearly water-tight, and their specific gravity was a little less than sea water. They were floated to their positions by being attached to one of the harbor punts, set at low water, and then filled with concrete. The ends were formed with alternate salient and re-entering angles, so as to lock into each other. The wall above low water was built of ashlar and rubble in the usual way; and the work was finished in a satisfactory and substantial manner in the summer of 1855. The length of the pier was fully 300 feet, the average breadth 70 feet, and the cost was under £10,000. The average cost of the brick masonry under low water was 7*d.* per cubic foot, or about one-half the cost of solid ashlar.

The work has now stood for nine years exposed to a rough sea and a heavy traffic, and is as perfect as when completed. Four years ago I had occasion to cut down the masonry to low water, in order to erect a 20-ton steam crane, which I constructed on the top of one of the brick masses as a foundation; and I found it then to be in the same condition as when set.

I had recently occasion to extend another of the quay walls, in water about 10 feet deep at low water; and this extension I resolved to construct in a similar way to the previous one, but in a cheaper manner. The bottoms were made of wood instead of iron, and the bricks were of two sizes, at the ordinary price, instead of the large size previously used, which cost nearly twice as much. I originally made the brick masses only 15 feet long, from a fear that larger sizes would be unmanageable. But having found them to be very easily handled, I resolved to make them on this occasion double the length, or about 30 feet long.

This extension was also successfully constructed in a very short time; and the drawings on the wall are intended to show the construction in detail. From the ground plan it will be seen that the extension is about 110 feet long, 35 feet broad, and the walls 27 feet deep.

The bottoms of the brick masses, which varied in length from 29 to 33 feet, were formed of a light wooden framing, formed of two beams of yellow pine 9 inches square, to which was spiked a platform of 3-inch white pine battens. These were caulked so as to be water-tight, and set on four logs on the bottom of the graving dock, as a foundation on which the brick caissons were to be built. The outer walls were formed of common bricks of two sizes—the one 9½ inches long, 4¾ inches broad, and 3½ inches thick; and the other 13 inches long, 6½ inches broad, and 3½ inches thick. These were laid in alternate courses—the small bricks in one course, and the large ones in another, header and stretcher alternately, so as to give proper bond. The outer walls were thus 20 inches thick all round, and the front and back walls were connected by three cross walls one brick thick. The whole was set in Roman cement, and strengthened with hoop-iron laid along the bed of the courses. The weight was adjusted, so that when finished they floated, with the top about one foot above the surface of the water.

The size was determined by the length of the logs from which the longitudinal timbers of the bottoms were cut. For these I selected logs varying from 29 to 33 feet long, and nearly 18 inches square, which were cut into four timbers, the full length of the log, so as to avoid any waste. The average size of the caissons was 32 feet long, 13 feet deep, and 10 feet thick. When the brickwork was finished, a small beam of timber was laid along the top, and connected with the bottom by means of two long bolts of wrought iron 2 inches in diameter. The water was then let into the graving dock, the brick masses or caissons were floated, and attached to the diving bell barge, or to a crane punt, and towed to the place where they were to be set. They could be raised about 4 inches above the line of flotation by means of the crane on the punt, and were suspended at this level above the bottom, by means of the long bolts above described, until they were brought to their exact position in the work, when they were at once lowered on to the bottom, and filled with concrete. When they were set in their places, the top beam and bolts by which they were suspended were removed and used again. The concrete used to fill them was formed with a mixture of good hydraulic mortar and cement, and large gravel, in the proportion of 1 of the mortar to 2 of gravel, which I found to set in a short time into a very hard compact mass. All the brick caissons were of an oblong form, with square ends, except the closing one across the end of the quay, which was formed with rounded corners to a radius of 13 feet. I found that forming the ends with salient and re-entering angles caused a great deal of trouble both in building and setting, and was of very little use.

These operations were all carried on without the slightest difficulty. As a proof of which, I may mention that on one occasion I built four of the caissons in the graving dock at once, and floated them into their places in two tides, thus completing 126 feet of wall in twenty-four hours. When the brickwork was finished the masonry was begun on the top, and completed with a facing of ashlar and a backing of rubble in the usual way; and the space between the walls was filled in with stones.

The cost of the work was £1881, or £51 per running yard, being less than the cost of open timber piling, which would have been greatly inferior both in efficiency and durability. The cost of the portion under low water was 4*d.* per cubic foot, concrete included.

I may mention that I am at present constructing another wall in a similar way, and that I have made some of the brick caissons even larger than I have stated. But from what I have seen, I think that about 40 feet long is the largest size which admits of their being easily handled.

Of course the possession of a graving dock offers great facilities for the construction of these floating masses of brickwork. But there is nothing to prevent them from being built on the beach in sheltered places by tide-work, and floated off at high water when finished; or they may be constructed on the ground above the level of high water, and launched on slip-ways like a ship.

Steel Bridges.

From the London Mechanics' Magazine, February, 1865.

At the meeting of the Literary and Philosophical Society on the 24th ult., Mr. S. B. Worthington, C. E., stated that he had lately constructed a swing bridge for carrying a railway over the Sankey canal, in which the girders are made of Bessemer steel plate. The object of using steel instead of wrought iron, was to reduce the weight of the girders. The girders are four in number, about 56 feet long, with bearings varying from 30 to 40 feet, and two feet deep. They were manufactured by Messrs. Benjamin Hick and Sons, of Bolton, from steel tubes made by the Bolton Steel and Iron Company; and were tested with loads of a ton to the foot, or more than double the weight which they could possibly be called upon to bear. The deflection varied from $\frac{1}{2}$ inch to 1 inch according to the length of the girder, and there was no permanent set on removal of the testing load.

The plates used varied from $\frac{1}{4}$-inch to $\frac{7}{16}$ in thickness; and the average tensile strength of a considerable number of plates tested, was upwards of 36 tons to a square inch. The weight of the girders was about $\frac{5}{8}$ of the weight which they would have been if wrought iron had been used. The contract for this bridge was made in November, 1863, and the bridge was erected during the past summer.

Bursting of a Reservoir.

From the London Mechanics' Magazine, Dec., 1864.

On the 31st ult., a catastrophe occurred at the seaport town of Harrington, Cumberland, similar in some respects to that which spread such devastation around Sheffield in the early part of this year, though upon a much smaller scale, and fortunately unattended with any loss of life. About 11 o'clock on that day a reservoir, three acres in extent, situated at a short distance from Harrington, burst, and deluged the main street with a wide stream described as some 4 feet or 5 feet in depth, which rushed down the street with a loud roar, the main body of water finally emptying itself into the harbor. The reservoir was one recently constructed to supply the new iron works of Messrs. Bain, Blair, and Patterson. It was constructed in a valley, the adjacent hills forming two sides, and the low end being shut in by an embankment about 300 feet in length and 20 feet high. This bank was 5 feet thick at the top, and it gradually spread out towards the base, sloping on either side. The sides were formed of battered earth and clay, a section of clay puddle being placed in the middle. It is about ten months since the construction of this reservoir was commenced, and it was almost completed when this catastrophe occurred on Wednesday. The recent heavy rains had filled it, and the by-fall which carries the overflow into a beck, and so into the harbor, proved inadequate to carry off the surplus water, which flowed over the side of the embankment, and, it is conjectured, washed away the earth on the outer side, and so gradually diminished the thickness of the embankment at one place, until it was incapable of resisting the pressure from within, and finally the water burst through, making a chasm some 10 feet wide.

Engineering Archæology.—The Historical Locomotives at Kensington.

From the London Builder, No. 1148.

People talk very glibly about invention and its progress, but we have often had occasion to notice that but few have any clear notion of what industrial invention really is, while a philosophic history of invention has yet to be written. Invention has been termed the poetry of science, and one popular belief about inventions would maintain that they are struck off like the stanzas of a poetical *improvisatore.* But very few inventions, however, could be traced to such a source, and the history of the arts shows that time, accident, and tentative experiment are, after all, the greatest inventors. One of the chief features observable in the maturity of any invention is its gradual and slow evolution, by the work of many brains, of many hands, of many circumstances of time, place, and chance. So slow and gradual is this progress, that the different stages in its history are as difficult to note as would be the progress of the hands of a clock unprovided with a dial-plate; and the different stages are difficult to determine, not merely with regard to entire machines or processes, but also with respect to the different details and minor operations making up these engines or these processes. As a natural result, when inventors or their descendants do at last come to understand the importance and value of what they have been doing, there take place endless controversies as to priority of invention. Witness that of the blast-pipe, for which there are several claimants. The importance, for reasons of social and commercial polity, of determining the laws of the development and progress of industrial improvement is scarcely recognized,—although the patent law and other laws bearing on inventions may be supposed to have some such theoretical basis. A generalization of this kind could only be conducted on a firm groundwork of historical truth, and there are many difficulties in the path of an investigation in this direction. To mention only one. There is scarcely one important modern invention which is not claimed for a distinct and different inventor in each of the more important civilized countries of Europe. The first originators of many of the different important steps in the elaboration of the steam engine are thus subjects of fierce contestation between the *savants* of England, France, and Germany. It would be scarcely possible to get at any true account of a question of this kind without studying the records and claims in these three languages at least. It is the French who show the greatest ardor and vivacity in these discussions; and, we regret to say, these patriotic sentiments have not in all cases been tempered with many scruples as to the means of maintaining, or rather of annexing, honor of this kind. We say this advisedly, having in our memory some yet unpublished discoveries as to the history of the steam engine.

We thus look upon the Museum of Patents at Kensington, mainly founded by Mr. B. Woodcroft, and greatly extended by the zeal of the present Curator, Mr. F. P. Smith, as being of yet greater importance than is generally acknowledged. This Museum, even in its comparatively undeveloped state, is not merely an historical record of inventive progress,—is not merely a museum of engineering archæology,—but it is also a place whence may be drawn some most valuable lessons towards a philosophic theory of the development of invention. One lesson, apparent to the most casual observer, is that an invention is not a thing of spontaneous, inspired production, but is rather a plant of slow growth,—sown, nourished, tended, and reaped by many different hands. This view is a rather disenchanting one to take, however true it may be. The popular imagination seems to always require a corporeal object for the embodiment of its fancies. It delights in a hero, its sight does not range so far over the intellectual horizon as to perceive a principle,—it can only see a person. It is forgotten that men's powers—the term being used in the widest sense—differ but little in extent from the physical stature of a given number of persons. The popular belief thus, for instance, invests Watt with the invention of the steam engine; Arkwright with that of spinning machinery; Fulton with marine propulsion by steam; George Stevenson with the first invention of the steam locomotive. A brief account of the locomotives already existing in the Kensington Museum of Patents would dispel this last belief, and even without greatly shortening Geo. Stevenson's status. At the time we write, too, the celebrated "Sanspareil," the river engine to Stevenson's "Rocket," built by Stevenson's rival, Timothy Hackworth, is just now being re-erected in the Museum, in company with its former competitor of the famous contest on the Manchester and Liverpool Railway, in 1829.

In the matter of priority of invention in, or rather of attempts at, land propulsion by steam, the French may well claim to be our *devan-*

ciers, and we do not think that any true Englishman will be inclined to grudge them this honor. The first steam carriage seems to have been made by a Frenchman, Cugnot, in 1769,—that same marvellous year which witnessed the birth of Napoleon I., Wellington, Humboldt, Mehemet Ali, Lord Castelreagh, Sir M. I. Brunel, Cuvier, and the first patent of Arkwright, the first patent of Watt, as also some other events almost as great in their eventual influence on the present era. An engine made by Cugnot is still in existence in the Conservatorie des Arts et Métiers at Paris. It has a copper boiler, very much like a common kettle without the handle and spout, furnishing with steam a pair of 13-inch single-acting cylinders. The engine propels a single driving-wheel, which is roughened on its periphery. Altogether, this engine bears considerable testimony to the mechanical genius of its inventor. It was unsuccessful, having got overturned once or twice on the very bad roads then existing in France, and it was put on one side. It is stated, however, that arrangements were made in 1801, to put it to work in the presence of Napoleon Bonaparte. The departure, however, of Napoleon for Egypt, prevented the trial,—a circumstance which recalls Fulton's subsequent unsuccessful negotiations with Napoleon for aid in attempting marine propulsion by steam. Watt then, in 1784, patented a locomotive engine, the boiler of which was to be "of *wood*," hooped like a beer barrel. Watt, however, had not much faith in steam carriages, and he objected to the attempts made in this direction in 1784 by William Murdoch, his very able assistant. The miniature engine made by Murdoch in that year is still carefully preserved at Soho. Careful and elaborate researches, such ast hose lately made by Mr. Zerah Colburn* into the history of the locomotive, seem to more and more confirm existing impressions as to the great part done by Trevethick in the introduction of the locomotive engine. In 1802, he and his moneyed partner Vivian patented the application of the high-pressure engine to steam carriages, and one of these was made, put to work in Cornwall, and exhibited in London. A model locomotive made by Trevethick in 1802, is now in the Museum of Patents, at South Kensington, having been found out in Cornwall by the present curator Mr. Francis P. Smith. The boiler is fitted with an internal double flue, and a chimney of small diameter. Mr. Colburn has shown clearly enough, and in spite of previous mis-statements, that Trevethick understood the value of the blast formed by the exhaust steam when turned into the chimney, and the practical sufficiency of the adhesion between smooth metallic surfaces for propelling the locomotive and its load. Trevethick's engine of 1804 was able to work over a rough tram-road at the rate of 5 miles an hour; but in Cornwall, where fuel was then so dear, the comparatively high quantity of coal consumed rendered this performance of inferior commercial value. The Northern districts of Newcastle-on-Tyne clearly offered the fairest opening for the childhood of the locomotive, and accordingly Mr. Blackett, the proprietor of Wylam Colliery, wrote in 1809 to Trevethick respecting his locomotive. It appears that, at the time, Trevethick replied that he was too much engaged; but in 1811, however, he sent an engine to Newcastle. It was not put on the Wylam railway, but set to drive a foundry.

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* "Locomotive Engineering." Glasgow: W. Collins, 1864.

At this time a locomotive was being made by Murray, of Leeds, at the order of Mr. Blenkinsop, of Middleton Colliery, near that town. It will be remembered that Mr. Blenkinsop's name is connected with the employment of a strong rack-rail on the line, into which worked a toothed pinion driven by the engine. A horizontally-placed cylindrical boiler was used, in which were placed two vertical steam cylinders. The boiler had a single internal flue, containing the grate at one end,—like a Cornish boiler—while the chimney rose out of the other end of the flue. A pair of cranks on each side of the engine drove a toothed wheel, and these two wheels themselves propelled a larger toothed wheel, on the axis of which was a pinion with coarse teeth working in the rack-rail. With such a light engine as one of 5 tons, and working at the slow rate of only 3 miles an hour, Mr. Colburn considers that we should be obliged to use a rack, and that thus Mr. Blenkinsop did not deserve the ignorant ridicule which has been directed against his rack and pinion. In fact, Murray's engines on Blackett's plan were the first locomotives ever worked permanently and on a commercial scale, and this line between Middleton and Leeds is in reality the first commercial railway. It is not, perhaps, generally known in England, but it is stated by Mr. Colburn, that "as late as 1848 the rack-rail was adopted upon an incline of 1 in 17, on the Madison and Indianapolis Railway," in the United States. "This incline, which has since been superseded by a line with practicable gradients, rose from the north bank of the river Ohio at Madison, and was about five-eighths of a mile in length." The engines provided had five steam cylinders in all, actuating, in a way not to be made clear without a sketch, a cogged wheel working on a rack-rail.

The next step was the commercial working out of the adhesion of the driving-wheels. This was done by William Hedley, the colliery viewer of Mr. Blackett, of Wylam; but it is probable that this would have been done by any one who first built a rather heavier engine than that of Murray's. Hedley thus, in 1813, constructed the engine now in the South Kensington Museum, but which has been at work near Newcastle, down to such a recent date as 1863. It has been known there many years under the name of the "Puffing Billy," a nickname given to its maker, Mr. William Hedley, by the colliery hands, from the fact of his being rather stout, with a consequent shortness of breath. Mr. Hedley first of all made an engine somewhat like that of Trevethick's, with a cast iron boiler, provided with a single internal flue, and working by adhesion on a smooth rail. This engine was not very successful, from a deficiency of boiler power, and from the fact of its having only one cylinder; but it clearly proved the possibility of doing away with the expensive and cumbrous rack. The "Puffing Billy" was then made. The inscription on it states that it was built in 1813, by Jonathan Foster, engineer, of Wylam Colliery, under the superintendence of Mr. Blackett, owner, and of Mr. Hedley, viewer of the colliery, in order "to haul coal-laden wagons along a railroad to Lemmington, where the coals were shipped in keels." This railroad was a substitute for the old tramroad, and was laid down on the site of the latter, between the years 1807 and 1811. The "Puffing Billy" has a wrought iron boiler, containing a return flue, the chimney being at the same level as the fire door. There are two vertical cylinders, driving beams centered each at one end, termed the "grasshopper" beam—a plan first due to Oliver Evans. The motion of the wheels is given to the four wheels by toothed gearing. An original document of great interest and instructiveness, is framed and glazed and hung to this engine. It appears that the noise and smoke made by this engine were considered a nuisance by some of the people living in the districts it traversed. They accordingly threatened to indite the "Puffing Billy" as a nuisance, and their complaints were so strongly urged, that Mr. Blackett found himself obliged to take counsel's opinion on the matter. The barrister, no doubt a noted one in his day, evidently agreed with the neighbors in their bad opinion of Mr. Blackett's engine. The case being put to him, he writes on the back of the document, that, "It does not appear to me that there is any objection arising from the lease itself, to Mr. Blackett's conveying his coal wagons by means of this steam engine; but I think that the use of such an engine may be deemed a nuisance to A. if the smoke and noise so occasioned thereby render his habitation unhealthy or uncomfortable; but this must entirely depend upon the quantity of smoke and noise occasioned, and the distance of the house of A. from the wagon-way," —(signed) R. Hopper Williamson, Newcastle, 12th September, 1814. But the most amusing bit is a note, apparently the result of an afterthought of the learned lawyer: "If the noise of this engine disturbs the cattle grazing on the land adjacent to the wagon-way, so as to injure them with regard to their feeding, I think it may be considered a nuisance." In all probability Mr. Williamson's capacity was rather above than below the average; but this is one of many more instances that shows the difficulties to be encountered in the introduction of any new thing. It is not very likely that such an opinion would now be given, or that we shall ever abolish locomotives for fear of disturbing the digestion of grazing cattle; but the first thing has been done, and the introduction of traction engines is just now greatly impeded by the same difficulties which beset the Puffing Billies of 1813. At the same time, it is clear that horses are more liable to be frightened by an engine on common roads than on a line,—or, rather, more properly speaking, the engine is brought within sight of a greater number of horses when it is made to travel on a common road. But it is well known that horses very soon get accustomed to a railway locomotive, and there is no doubt that they would just as soon forget their fear with the traction engine.

About a couple of years after the construction of the "Puffing Billy," Mr. Hedley built a yet more efficient engine for the Wylam Railway. In the same way as he had first put to commercial use the adhesion of smooth surfaces for railway traction, so did he first apply the return flue boiler and the narrow chimney. By the way, talking of "adhesion," we think that this term is often used very improperly. Adhesion only takes place between two surfaces of the same substance of the same—or of nearly the same—molecular structure, and consequently similar surface. Adhesion thus does not take place between a cast iron surface and a wrought iron surface,—between (say) a cast iron wheel and a wrought iron rail. The grip is in this case produced by simple friction without any adhesion, properly so called.

A careful observer of the doings on the Wylam Railway was Geo. Stevenson, and he persuaded his employers at the Killingworth Colliery to construct an engine which was finished towards the middle of 1814. Its boiler, 8 feet long and 34 inches in diameter, was carried on four 3-feet wheels, and provided with a single internal flue. Two vertical cylinders were placed for half their length in the boiler. The motion for driving the wheels was almost the same as that in the "Puffing Billy." It is stated by Mr. Smiles that the speed of this first engine of Stephenson's was only three miles an hour; a year's trial with it showed that it had no advantage in point of economy over horse power,—being thus much inferior to Hedley's engines. This weakness of Stephenson's first engine was due to the low boiler power produced by the use of a single flue and a chimney of large diameter with its weak blast, unaided by exhausting the waste steam into the chimney. In 1815, Stephenson made his second engine according to the patent which he took out in that year. A different kind of gearing was adopted for driving the engine, and additional adhesion was obtained by coupling the wheels of the tender to the engine by means of an endless chain. Stephenson also used springs, according to a suggestion of Mr. Nicholas Wood. George Stephenson also applied a strange and even absurd scheme to some of the Killingworth engines as a substitute for springs. This consisted in adapting a number of pistons sliding in cylinders fixed to the bottom of the boiler, and in communication therewith. Stephenson, in his own words, supposed that as they "acted upon an elastic fluid, they produced the desired effect with much more accuracy than could be obtained by employing the finest springs of steel to suspend the engine." Of course the plan had to be at last abandoned, after some unsuccessful trials. At this time, and some years previously, the placing of steam-carriages on common roads was being attempted,—a feat which is now being carried out in our own time mainly for agricultural purposes. The wedding of the wheel and the rail put an end for the time to the experiments in this direction, conducted by Griffiths, Gurney, and others. Mr. Colburn remarks on these experiments, that while road locomotives had ample adhesion, they only lacked evaporative power. "The steam blast, which for railway engines running at a slow speed, and having insufficient adhesion, was as yet hardly required, nor, for some of these engines, even admissible, was therefore of great importance to the road locomotive engineers. Goldsworthy Gurney, then a surgeon and lecturer at the Surrey Institution, has claimed the discovery of the steam-jet in 1820,—the year, by the way, in which Nicholson's patent for various applications of the steam-jet expired. In 1820 and 1821, Gurney employed the jet for promoting combustion in laboratory furnaces, for decomposing various compound bodies, and for working platinum; in 1824 he applied jets of steam, taken directly from the boiler, to increase the draught in the chimneys of the steamboats *Alligator*, *Duchess of Clarence*, &c.; in 1826 he applied steam in the same manner to increase the draught in the chimney of his road-locomotive; and in an *ex parte* statement not long ago published by Mr. Gurney, he alleges that he "supplied Timothy Hackworth with the blast-pipe employed by that engineer in the locomotive 'Sanspareil,' which so nearly won the Liverpool and Manchester prize in 1829." It would seem, however, that Hackworth used the single contracted blast orifice about two years previously to 1829.

Timothy Hackworth was a practical engineer of much ability, and, though not so successful as George Stephenson, it is probable that his mechanical powers were little, if at all, inferior. He helped to make the "Puffing Billy" at the Wylam Railway; in 1824 he was the manager of George Stephenson's locomotive foundry at Newcastle; becoming, in the following year, the locomotive superintendent of the Stockton and Darlington Railway. The engines of this line opened in 1825, were made by Stephenson, and they gave such bad results that it was stated that the directors, as late as 1827, were thinking of altogether giving up locomotives. Hackworth, however, took in hand one of the engines on the line, made by Wilson, of Newcastle. Hackworth applied the return-flue to the boiler, and, above all, he applied to it the blast-pipe. The "Royal George" was thus the best locomotive of its time, as it was, besides, fitted with the then novelties of "a cistern into which a portion of the exhausted steam could be turned to heat the feed-water; it had short-stroke force-pumps, worked by eccentrics; adjustable springs, instead of weights, upon the safety valves; and a single lever reversing-gear."

Two years after the application of these improvements to the "Royal George," in 1829, took place the Rainhill trials on the Manchester and Liverpool Railway, which had the effect of bringing to a head most of the existing knowledge in locomotive traction. One of its most important results was the first application of the multitubular boiler to the locomotive. The invention of this important form of boiler has afforded, and still affords, a field for both intestine and international wars as to its priority of invention. The English claim the multitubular boiler; so do the French; and so do, we believe, the Americans. Perhaps a Chinese claim may be yet put forward. In the mean time, Mr. Colburn shows that it was first prepared by a London engineer, Mr. James Neville, of Shad-Thames, in specification No. 5344, A.D. 1826. This is an important document in engineering archæology, as it annihilates the pretensions of the French claimant, M. Marc Séguin, who only patented the multitubular boiler in France in 1828.

Thus were combined and brought into practice all the essential points of the present locomotive, which has only been since improved by, in the main, the mere effect of time,—of time and experiment, eliminating inferior forms of detail. Nevertheless, the then existing locomotives were by no means very successful machines; such distinguished engineers as Messrs. Walker and Rastrick reported against their use on the Liverpool and Manchester Railway; and they were confirmed in their impressions by a man of such ability as Mr. Nicholas Wood, who (just as Smeaton firmly believed that steam-engines could never do better work than pumping up water for water-wheels) gave it as his conviction that no locomotive could be made to go faster than 8 miles an hour. Thus, even so late as the spring of 1829, the directors of the Liverpool and Manchester Railway were thinking of applying fixed engines and ropes for working the line. Fortunately, however, the counsels of two or three members of the board prevailed, and it was decided to make a last trial of locomotives. As one of George Stephenson's engines had already failed on the line, a prize of 500*l.* was publicly offered to all comers on the 25th of April, 1829.

The conditions that engines had to fulfil have been often published. One of these was, that the engines should burn their own smoke; and it is a pity that this "condition" has not even now been fulfilled, as every railway passenger knows to his cost. The only engine ready at the appointed time was the "Rocket," entered by Robert Stephenson; Hackworth's "Sanspareil," Braithwaite and Ericsson's "Novelty," and Mr. Brandreth's "Cyclops" were not ready at the appointed time. The "Rocket" and the "Sanspareil" (both somewhat altered) are now in the Kensington Museum, the last, as we have stated, being just now there re-erected. Both are four-wheeled engines. The boiler of the "Rocket" is traversed by a number of copper tubes, and its two inclined cylinders work crank-pins on the driving-wheels at the front or smoke-box end of the engine. The honor of the application of the tubular boiler is not due to the Stephensons, but to Mr. Booth, the secretary of the Liverpool and Manchester Railway. The diameter of the driving wheels was 4 feet 8½ inches, and that of the traveling-wheels, 2 feet 6 inches.

With regard to the "Sanspareil," it is stated that this was the second engine to which was applied the blast-pipe, the "Royal George" (1827) being said to be the first.* The exhaust steam from each engine is taken into the chimney through a blast-pipe. It also appears to have been one of the first engines with coupled wheels, of which it had four. The most striking peculiarity to the eye accustomed to the present locomotive is, that the driver stood beside the chimney, the boiler being completely traversed by a return flue. The boiler is cylindrical, about 4 feet in diameter and some 6 feet long. The fact that the apparent front end is in reality the hind portion which was coupled to the tender, has misled some of the writers of treatises on the steam-engine, causing them to figure the tender in front. An inspection of the engine would appear to show that the driver stood on the tender in order to fire the boiler. The cylinders are vertical, and, in the original engine, were 7 inches in diameter, the stroke being 18 inches. The two front wheels are fitted with crank-pins, driven by the connecting-rod of each engine. The "Sanspareil" was tried on the 13th of October, 1829. The total weight of the engine and load being 19 tons 2 cwt. The failure of the feed-pump, however, led to its stoppage, as the boiler could not be kept filled with the necessary water. It was also unfortunate with regard to one of the steam cylinders cracking through the bore into the steam vent. The rate of evaporation, and consequent tractive power of the "Sanspareil," was, however, higher than those of the "Rocket," the successful engine. It is stated by Mr. Hick, of Bolton, the donor of the engine to the Kensington Museum of Patents, that it was purchased by the Liverpool and Manchester Railway, after the trials. In 1831 it was sold to Mr. T. Hargreaves, of Bolton, in order to work on the Bolton and Leigh Railway. In 1837 the old cylinders were replaced by new ones of larger dimensions, and the original wheels with wooden spokes were replaced by cast iron wheels, with hollow spokes. It continued till 1844 on the Bolton and Leigh Railway, but was, by that time, found too small and weak. Mr. Hargreaves then removed it to his colliery at Cophall, near Chorley-lane, and fixed it over a coal-pit, in order to drive a pumping and winding apparatus, a pair of wheels being removed for a set of toothed gear. The boiler was not used, the engine being driven from a stationary boiler. It thus worked up to the end of 1863, when it was removed solely in consequence of the coal-pit being exhausted. Mr. Hick, of Bolton, happened to pay a visit last year to the Kensington Museum, and, having seen the other engines there of historic fame, he determined to add the "Sanspareil" to the number. Mr. Hargreaves then presented the engine to Mr. Hick, who, in his turn, gave it to the Museum, where, in the words of Mr. Hick's letter, the engine, after all its chequered and eventful career, may end its destiny "in peace and not in pieces." It may not be uninteresting to state, that the railway companies on the road from Bolton to Liverpool carried the old engine free of cost, according to the suggestion of Mr. F. P. Smith, that the venerable engine which had carried so many, should, in its turn, have its own carriage frankèd to its last resting-place.

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* See the London *Quarterly Review* for 1858, and the *Practical Mechanic's Journal* for 1850 and 1851.

The "Novelty," though very unsuccessful—as it was very soon disabled by an accident—displayed high constructive power, and is considered by some good judges as being in many respects the best designed engine of the four. It was a four-wheel tank engine; its boiler consisted of an upright cylinder for the fire-box, and a horizontal barrel 15 inches in diameter, and about 12 feet long. The flame was taken from the fire-box through the barrel by means of a tube folded backwards and forwards on its way to the chimney. The two steam-cylinders were placed vertically in the framing, being 6 inches in diameter, with a 12-inch stroke. The diameter of the wheels was 4 feet 2 inches. Mr. Burstall's "Perseverance" very soon gave up, and was found unfit for the trials.

It would be a natural remark to make, that the greater number of the engines and machines which have been so long at work have been greatly altered from the original construction by the exigencies and accidents of practical wear and its attendant repairs. Like John's old knife, which still remained "John's old knife," though it had received about half-a-dozen new blades in succession, and about as many new handles, it might be doubted whether these engines really represent their original construction. In one sense this may be true, and it is probable that only a portion of the original raw metal is still in combination. But then it must be remembered that in piecemeal repairs any part repair is in a great measure tied to the original form. The new blade of the old knife has to conform to the existing handle, and the new handle has to be made to the shape of the blade. The same must be, more or less, the case with repairs to an engine or machine. At the same time, such a consideration points to the absolute necessity for a correct history—or rather engine biography—being appended to each engine, pointing out where and what alterations and repairs have been made.

The Patent Museum at South Kensington, only yet needs the "Novelty" to complete the trio of the engines which figured at the great Rainhill contest. It is not now known where the "Novelty" at present is, or indeed, whether it is even still in existence. We believe that Mr. F. P. Smith is anxiously looking about for it, and we hope that he may be successful in his search. What lessons of the way in which "Fortune turns her wheel," may be read by a look at these old engines,—the progenitors of the apparatus,—the use of which is stamping its impress on present life in so many direct and indirect ways. The two Stephensons are now dead, but their engine, which killed Mr. Huskisson, raised their fortunes above those of perhaps any other engineers of their time. Timothy Hackworth is now dead, but his works at Newcastle, like those of the Stephensons, are still flourishing. The Messrs. Braithwaite are now living, but their factory has been given up, and their partner of 1829, the Swedish engineer, Ericsson, is now building "Novelties," in the way of gunboats for the Federals. In centuries hence, time will have thrown its halo of distance round these engineers, and their doings will be scanned with a kind of romantic interest. Let us hope that, in the course of the next century, the Government will have provided a decent building for the objects which represent such important interests, but which are now sheltered in the crowded and dark shed at South Kensington.

For the Journal of the Franklin Institute.

General Problem of Trussed Girders. By De Volson Wood, Prof. C.E., University of Michigan.

Continued from page 107.

20°. It is found by subjecting equation (65) to experiment, that R is not constant for beams of different forms, when made of the same material. It is also found that the value of R which is found from rectangular beams does not equal the ultimate resistance of the material to tension or compression.

For instance, if a rectangular wooden beam be suspended at its ends and broken by a weight P placed at the middle, we have, from the formula which was deduced for this case in the preceding article,

$$R = \frac{3 P l}{2 b d^2}$$

in which all the quantities in the second member may be measured, and hence R may be found. Now, bearing in mind, that, in this case R is the ultimate resistance of a unit of fibres most remote from the neutral axis, and we would expect to find that it equals the force necessary either to pull asunder, or to crush a bar of the same material whose section is unity, when the force is applied in the direction of the length.

But an examination of tables, in which are entered the ultimate resistances to tension, compression, and values of R, shows that the disagreement is too great and too uniform to be attributed to errors of experiment. There is a very good table of this kind in the appendix of "Mosley's Mechanics and Engineering." A careful examination shows that the value of R is generally, indeed almost always, between the others. For instance, if the resistance to tension—which we will hereafter call S,—is greater than the resistance to compression—which we will call C;—then we find that R is less than S and greater than C. This is the case with wrought iron and most kinds of wood. If C be greater than S, R will be less than C and greater than S, as in the case of cast iron. We find the same result by comparing tables in Weisbach's Mechanics and Engineering.

Hence we infer *that the theory is not perfect; in other words, it does not represent the true law of resistance of beams.*

This fact induced Professor Barlow, a few years since, to investigate the law of resistance more carefully and more thoroughly than ever before; and as a result he announced a new law, called "*The Resistance to Flexure.*" I consider the term unfortunate; for all the resistances in a beam which resist bending may properly be called "*resistances to flexure*," but he intended to include only a certain class of resistances which he thought was developed by bending, and the value of which he tried to determine at the instant of rupture. I think it may more properly be called "*a resistance to longitudinal shearing.*"

He reported the results of his investigations to the Royal Society (England) in 1855, and afterwards published the data, experimental and analytical results upon which the theory is founded, in the *Civil Engineer and Architect's Journal*, vol. xix, page 9, and vol. xxi, page 111. They are also published in the *Journal of the Franklin Institute*, vol. xxxii, pp. 4 and 73. These articles from a scientific point of view, are looked upon as among the most valuable that have ever been written upon this subject.

His complete theory involves *two laws* of resistance; the *first* of which is essentially the same as that given in the preceding number, 19°; and the second of which he calls "*the resistance to flexure.*"

The first *law* includes, and is founded upon, the following principles:

1. The fibres on the convex side are extended, and those on the concave side are compressed.

2. There is a neutral surface, along which the fibres are neither extended nor compressed.

3. The resistance to extension and compression varies directly as the distance of the fibre from the neutral axis.

4. The ultimate resistance which acts along the most remote fibre is S on the side of tension and C on the compressed side: S being the tenacity of the material for a unit of section, and C the resistance to crushing per unit of section.

The second *law* is founded upon the following principles:

1. The *longitudinal shearing* is a resistance acting in addition to the direct extension or compression; and is really the cohesive resistance which is developed between two adjacent planes of fibres which are unequally elongated or compressed.

2. This resistance is evenly distributed over the transverse section; and, consequently, (within the limits of its operation) its centre of action on the compressed part will be at the centre of gravity of the compressed section; and, similarly, in respect to the extended part. This resistance per unit of section Barlow calls φ.

3. It is proportional to and varies with the *inequality* of strain between the fibres nearest the neutral axis and those most remote, and hence

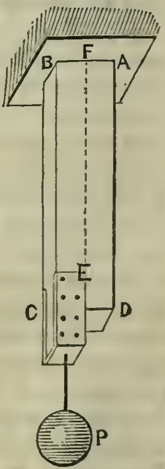
4. The "resistances to longitudinal shearing" in open built beams will be to that in a solid beam of the same material at the instant of rupture, as the depth of the solid part, is to the distance of the outside of the solid part from the neutral axis.

5. Sections which were normal to the axis of the beam before flexure, will remain normal during flexure.

6. Rupture of solid beams will take place when the strain on a unit of section of the fibres most remote from the neutral axis, is $S + \varphi$ or $C + \varphi$, according as one or the other is first reached.

To show more clearly the nature of the longitudinal shearing, I will refer to an example given by Barlow. Suppose that P, in Fig. 30, is just sufficient to pull asunder the bar F B C E, in which case it is supposed that all the fibres are equally strained, and each unit resists a force equal to S. Now if another bar, A B C D, were substituted for the former, and P applied to the same section, C E, it is evident that P would not break the bar; for the fibres just at the left of F E, will restrain those just at the right, so that they will not be elongated as much as they would if the part A F E D were removed. The restraining of the fibres just at the right of F E will have its effect upon the next plane of fibres, and so on to B C. Now this restraining influence, this cohesion between the

FIG 30



fibres is the "resistance to longitudinal shearing;" and it is evident that a portion of the force P, must be absorbed in overcoming it, so that it cannot produce a strain of S on the fibre B C.

A phenomenon similar to this takes place in a bent beam. The fibres unequally distant from the neutral axis are unequally strained, and hence develop the "longitudinal shearing;" and it seems evident that this strain absorbs some of the bending force. Hence, it takes a greater force to produce a strain S on the outer fibres, than it would if this resistance did not exist.

Although this theory seems rational, yet it remains to be seen whether it is the *true* one, or even whether it is better for practical purposes than the theory commonly used.

In analyzing it, we observe that all the resisting forces are parallel to the axis of X; and taking the applied forces parallel to the axis of Y, and we will immediately obtain equations (61) and (62); and hence the remarks which follow them apply to this theory.

I will now show how to develop the third of equations (62). Suppose that the beam ruptures on the side of tension. Let the origin be on the neutral axis; d_1 the distance of the most remote fibre from the neutral axis; and the other notation as in number 19°. Then proceeding as we did to obtain equation (65), and we find for the resistance according to the first law above named, $\frac{SI}{d_1}$; and according to the second law $\varphi\iint ydydx$. Hence, the moment of resistance is,

$$\Sigma Fy = \frac{SI}{d_1} + \varphi\iint ydydx \quad . \quad . \quad (84)$$

If the beam be rectangular, and the neutral axis at the centre of the section, b the breadth, d the depth, then $I = \frac{1}{12} b d^3$; $d_1 = \frac{1}{2}d$

$\int_0^b \int_{-\frac{1}{2}d}^{+\frac{1}{2}d} y\,dy\,dx = \frac{1}{4}bd^2$; and (84) becomes

$$\Sigma Fy = \frac{bd^2}{12}(2S + 3\varphi) \quad . \quad . \quad . \quad (85)$$

If the beam be supported at its ends, and P be applied at the middle; we have $\Sigma Fy = \frac{1}{4}Pl$, and (85) becomes,

$$2S + 3\varphi = \frac{3Pl}{bd^2} \quad . \quad . \quad . \quad . \quad (86)$$

If $\varphi = 0$, equation (86) reduces to the *form* which is commonly used. It is evident that two experiments are necessary in order to determine both S and φ; but they can be more satisfactorily determined by taking a large number of experiments, and reducing the equations by the method of least squares.

If the theory be correct, the value of S thus found should be the same as that found by pulling a bar asunder by a force applied in the direction of its length. Barlow found for cast iron that $\varphi = 0{\cdot}85\,S$ for a mean value; and for wrought iron $\varphi = \frac{1}{2}$ s nearly. (*See Civ. Eng. and Arch. Jour.*, vol. xxi, pages 114 and 116.)

This "longitudinal shearing resistance" not only has a value at the instant of rupture, but must act during all the stages of flexure up to the instant of rupture. The actual deflection therefore should be less than that found by the theory in common use; but as the observed deflections are generally small, no marked discrepancy between computed and observed results has, so far as I know, been detected.

21° *To find the position of the neutral axis.*

This may be found experimentally or analytically. The former has great advantage over the latter for any particular case, but the latter is essential for general purposes. The former must be resorted to, to confirm or vitiate a theory.

Position found by Experiment.—I will note a few examples where it has been determined experimentally.

Barlow made a very delicate experiment upon a solid rectangular cast iron beam, supported at its ends and loaded at the middle, in which he found the neutral axis to coincide exactly with the axis of the beam. (*See Civ. Eng. and Arch. Jour.*, volume xix, page 10.) He found the same result with a wrought iron beam under similar circumstances. (*See same Journal*, vol. xxi, page 115.) For malleable iron he found it to be $\frac{1}{4}$ or $\frac{1}{5}$ the depth of the beam from the compressed side. (*See Barlow's Strength of Materials*, page 330.) It should be observed that this experiment was made several years before the former ones, and that the means employed were not as delicate as in former examples. It is possible that a more careful experiment would show it to be nearer the centre of the sections than that given above.

A valuable set of experiments was made at the "Conservatorie des Arts et Méliers" in 1856, from which I infer, that in a wrought iron beam whose cross section is a double T, the neutral axis passes through or very near the centre of gravity of the sections. (*See Morin, Résistance des Matéraux*, page 137.) In the same work on pages 129, 130 and 131 are given the results of experiments upon rectangular wooden beams of various qualities, which show that it passes through or very near the centre of the transverse sections. So far as these examples are concerned the results are conclusive, and very strongly indicate that it generally coincides with or is very near the centre of gravity of the sections, when the deflecting force acts normal to the axis of the beam.

Position found by Calculation.—It is well known that within the elastic limits, the resistance of any fibre to extension is directly proportional to its elongation, and the latter is proportional to the modulus of elasticity. This is also true, to some extent, considerably beyond the elastic limit; but in the state bordering upon rupture it is not true, and it is difficult to measure the strains in any way so as to make them available for analytical purposes.

A. *Suppose that the deflecting forces are normal to the axis of the beam;* then we have only to develop the first of equations (61).

a. Let the strains upon the fibres be directly as their distances from the neutral axis.

I will first investigate those cases in which the elastic limits are not passed.

1. Let the modulus of elasticity for tension equal that for compression.

Let R_t = the strain upon a unit of fibres most remote from the neutral axis on the side of tension.
R_c = similar strain on the compressed side.
d_t = the distance of the most remote fibre from the neutral axis on the side subjected to tension.
d_e = similar distance on the compressed side, and other notation the same as before used.

The elongations of the fibres on one side of the neutral axis, equal the compressions of those on the other side which are equally strained; and because the strains are directly proportional to the distance of the fibres from the neutral axis, we have

$\frac{R_t}{d_t} = \frac{R_c}{d_c} = s =$ the strain at a unit's distance from the neutral axis; and at any distance y, the strain is $s\,y$;

$\therefore s\,y\,dy\,dz =$ the strain on any elementary fibre.

Hence after integrating once, we have $s\int_0^{d_t} zy\,dy$ which integrated so as to include the total extended part, gives the total tension. Similarly $\int_0^{d_c} zy\,dy$ gives the total compression. Observing that the angle between these forces is 180°, and we have by substituting in the first of (61)

$$s\int_0^{d_t} zy\,dy - s\int_0^{d_c} zy\,dy = 0$$

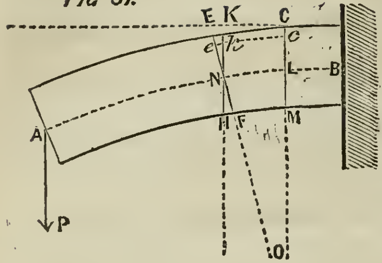
$$\text{or} \int_0^{d_t} zy\,dy + \int_{d_c}^{0} zy\,dy = \int_{d_c}^{d_t} zy\,dy = 0 \quad . \qquad (87)$$

Now from the mechanics we know that the ordinate of the centre of gravity of any section is

$$\bar{Y} = \frac{\int zy\,dy}{\int ydz},$$

and if the origin be at the centre of gravity, $\bar{Y} = 0, \therefore \int zy\,dy = 0$, which is the same as (87). Equation (87) was obtained by taking the origin on the neutral axis; hence *the neutral axis coincides with the centre of gravity of the sections.*

FIG 31.



2. Let the moduli of elasticity be unequal.

Let E_t = the modulus of elasticity for tension,

E_c = the modulus of elasticity for compression,

$y = \text{N}\,k$ = any ordinate, fig. 31,

$\lambda = k\,e$ = the elongation of the fibre at k,

$d\,x = \text{L N}$ = the distance between two consecutive sections.

$dy\,dz$ = the area of a fibre,

p = the force which would produce an elongation or compression equal to λ of any fibre.

Let a beam be bent under the action of any number of parallel forces which are normal to its axis, so as to produce the neutral axis A N L B, Fig. 31.

Let C M and K H be two consecutive sections and normal to the neutral axis before flexure, then since they remain normal during flexure they will take the position of C M and E F, and will meet if produced in some point, as O.

Now, instead of the deflecting forces, we may conceive the beam to be severed along the plane K H and a force applied to each fibre acting in the direction of its length, those above L N elongating, and those below compressing the fibres, and each acting with such intensity as to produce the same elongations and compressions as the deflecting forces. Let p be one of the forces, producing an elongation or compression equal λ. We know that within the elastic limits, the force necessary to produce this elongation varies directly as the modulus of elasticity, the section and the elongation, and inversely as the length of the bar; hence,

$$p = \frac{E_t\,\lambda\,dy\,dz}{d\,x} \text{ or } = \frac{E_c\,\lambda\,dy\,dz}{d\,x} \quad . \quad . \quad (88)$$

according as it is tensive or compressive.

But because the sections remain normal to the neutral axis, we have from the similarity of triangles.

$$\frac{\lambda}{y} = c = \text{constant}, \quad . \quad . \quad . \quad (89)$$

equal the elongation or compression of a fibre at a unit's distance from the neutral axis.

$$\therefore \quad \lambda = c\,y \text{ which in (88) gives}$$

$$p = \frac{c\,E_t\,y\,dy\,dz}{dx} \text{ or } \frac{c\,E_c\,y\,dy\,dz}{d\,x} \quad . \quad . \quad (90)$$

Hence the total tensive force is $\dfrac{c\,E_t}{d\,x}\displaystyle\iint_0^{d_t} y\,dy\,dz$

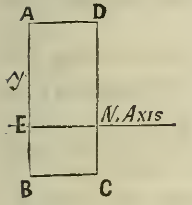
and the total compressive force is $\dfrac{c\,E_c}{d\,x}\displaystyle\iint_0^{d_c} y\,dy\,dz$;

hence the first of (61) becomes

$$E_t \iint_0^{d_t} y\,dy\,dz - E_c \iint_0^{d_c} y\,dy\,dz = 0 \qquad (91).$$

Equation (91) can be solved when the form of the section is known.

FIG 32



EXAMPLE.—Suppose the sections are rectangular, Fig. 32.

Let $AD = b$, $AB = d$,

$y = AE =$ the superior limit,

$d - y = EB =$ the inferior limit,

$\frac{E_t}{E_c} = r$, for convenience.

Take the origin at E,

Then (91) becomes $r \int_0^b \int_0^y y\,dy\,dz = \int_0^b \int_0^{d-y} y\,dy\,dz$

or $\frac{1}{2} r\,b\,y^2 = \frac{1}{2} b\,(d-y)^2$

$$\therefore y = \frac{d}{1+\sqrt{r}} \qquad . \qquad . \qquad . \qquad (92)$$

If $r = 1$; $y = \frac{1}{2} d$,
$r = 0$; $y = d$,
$r = \infty$; $y = 0$.

If y is known, the ratio of the moduli are easily found; for by (92) we have

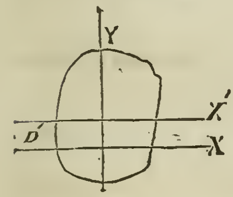
$$r = \left(\frac{d-y}{y}\right)^2 = \frac{E_t}{E_c}$$

Equation (91) is not so easily solved for the more complex forms.

3. To find the position of the neutral axis so as to give a minimum strength.

To solve this we have to make the first member of (65) a minimum.

FIG 33.



We assume that R is the same for all positions of the neutral axis. We have called I the moment of inertia about the line of intersection of the neutral plane and the section.

Let $I' =$ the moment of inertia about an axis parallel to the former and which passes through the centre of gravity,
$D =$ the distance between the axis,
$A =$ the area of the section,
$a =$ the distance of the most remote fibre from the axis which passes through the centre,
$d_1 = a + D =$ the distance of the most remote fibre from the neutral axis.

Then from the well known formula of reduction, we have

$$I = I' + D^2 A.$$

Hence, the first member of (65) becomes

$$\text{R}\,\frac{\text{I}}{d_1} = \text{R}\,\frac{\text{I}^1 + \text{D}^2\,\text{A}}{a + \text{D}} \quad . \quad . \quad . \qquad (93)$$

which is to be a minimum. Observing that I^1, a, D, and A are constants; and differentiating, placing equal zero and solving, gives,

$$\text{D} = -\,a \pm \sqrt{a^2 + \frac{\text{I}^1}{\text{A}}} \quad . \quad . \qquad (94)$$

The positive value of D makes the second differential co-efficient positive; hence, it is the minimum; and the negative value is the maximum. The maximum value is really the minimum of the negative values.

Examples.—1. Suppose the sections are rectangular. Let d be the depth, and b the breadth.

Then $a = \frac{1}{2}d$; $\text{I}^1 = \frac{1}{12} b\, d^3$; $\text{A} = b\, d$,
which in (94) gives

$$\text{D} = \begin{cases} +\,0{\cdot}07732d \\ -\,1{\cdot}07732d \end{cases}$$

The positive value in (93) gives $\text{R}\,\frac{\text{I}}{d_1} = 0{\cdot}1547\,\text{R}\,b\,d^2$. . (95)

If the neutral axis passes through the centre of the sections, $\text{D} = 0$ and (93) gives $\frac{1}{6}\,\text{R}\,b\,d^2 = 0{\cdot}1666\,\text{R}\,b\,d^2$. . . . (96)

2. Suppose the sections are circular.

Then, $a = r$; $\text{I}^1 = \frac{1}{4}\pi r^4$; $\text{A} = \pi r^2$

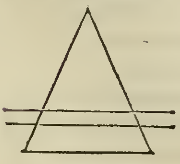
$$\therefore \text{D} = \begin{cases} +\,0{\cdot}11807\,r \\ -\,1{\cdot}11807\,r \end{cases}$$

$$\text{and } \text{R}\frac{\text{I}}{d_1} = 0{\cdot}7415\,r^3\,\text{R}.$$

If the neutral axis passes through the centre of gravity of the sections $\text{D} = 0$ and (93) becomes

$$\text{R}\,\frac{\text{I}}{d_1} = 0{\cdot}7854\,r^3\,\text{R}$$

FIG 34



3. Let the sections be isosceles triangles, Fig. 34.

Let $d =$ the altitude, $b =$ the base.

Then, $a = \frac{2}{3}d$; $\text{I}^1 = \frac{1}{36}\,b\,d^3$; $\text{A} = \frac{1}{2}\,b\,d$

$$\therefore \text{D} = 0{\cdot}0403\,d$$

$$\therefore \text{R}\,\frac{\text{I}}{d_1} = 0{\cdot}04043\,d$$

If $\text{D} = 0$ we have $\frac{\text{RI}}{d_1} = 0{\cdot}04166\,d$

This analysis leads to some interesting considerations. According to the second hypothesis it appears that the neutral axis will be nearer the side which has the greater modulus of elasticity. That is, if the modulus for compression is greater than for tension, the neutral axis will be nearer the compressed side. But the modulus for compression is nearly the same as for tension in all the materials with which the engineer has to deal; hence, so long as the elasticity is unimpaired, the neutral axis passes *very near* the centre of the sections. But as the strains are increased, and the elasticity becomes impaired the third hypothesis shows that the neutral axis moves from its original position towards the side which offers the greatest ultimate resistance to the strain, until, at the instant of rupture, the distance between the centre and neutral axis is D, equation (94).

The latter reasoning furnishes an amusing paradox; for if, in a rectangular beam, we suppose that the ultimate resistances to compression and tension, as well as the moduli of elasticity, are exactly equal, it follows that both sides of the beam would be equally impaired by the strains; and hence, the neutral axis could not move, but must remain at the centre, in which case, the beam would be stronger than if one of the resistances were slightly increased.

The relative strength of the beam in the two cases is shown by equations (95) and (96). The paradox is purely theoretical, for no material is so perfectly homogeneous as to realize the conditions upon which it is founded.

If a rectangular beam be supported at its ends and is broken by a weight P, applied at the middle, we know that the moment of the weight is $\frac{1}{4}Pl$; and this must equal the moment of resistance; hence we have,

according to equation (95) $0{\cdot}1547\,Rbd^2 = \frac{1}{4}Pl$ (97)

" " (96) $0{\cdot}1666\,Rbd^2 = \frac{1}{4}Pl$ (98)

We see that the same general law holds in these equations; viz: that the resistance of a rectangular beam varies directly as the breadth and square of the depth, and inversely as the length.

We have supposed that R is constant, and hence must be determined by means which are independent of any theory of transverse resistance, unless we succeed in establishing the true theory; for each theory gives a value peculiar to itself.

Thus, in equations (97) and (98); all the quantities except R may be found by direct measurement and R found by simple computation; but the two equations give different values. It makes no difference which equation is used, provided we use the same one in practice that we do for obtaining the value of R; but unless the theory be correct R must be determined for each form of beam used in practice. When the true theory is established, it will give the same value for the constants in all forms of beams which are made of the same material.

I am not aware that the last hypothesis has been investigated before, and I have not now the time to apply it to experiments to see if it possesses much merit. A glance at it, however, inclines me to the opinion that it possesses little or no advantage either theoretically or practically over the commonly received hypothesis which fixes the neutral axis at the centre of the sections. In connexion with Barlow's theory it may be found to be of great value. In my next I will develop the formulas which will be applicable to the case.

(To be continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

Experiments on the Trompe.

From the London Mechanics' Magazine, October, 1864.

The trompe is a species of blowing machine, which is used in mountainous countries for producing a blast of smelting operations. As now constructed it consists of a large cistern, from the bottom of which proceed two vertical tubes about 20 feet long; the lower ends of the tube pass into a wooden wind chest, furnished with a blast pipe for the exit of air, and also with an arrangement for keeping water within at a constant level. Immediately below the point where the tubes enter the water cistern each tube is constricted, and a few inches beneath the constriction several holes are bored in the circumference of the tubes, so that air may have free access to their interior. When water is allowed to fall from the water cistern through the tubes, a quantity of air is carried down by the descending stream, which air separates from the water, as soon as it has entered the cistern, and rushes from the blast pipe in a continuous current.

In the *Philosophical Magazine* for last month, Mr. Rodwell has detailed a number of experiments which he made in order to determine "the most favorable conditions under which air is carried down by a stream of water, and to arrive at a satisfactory explanation of the cause of the descent of air in the different modifications of the trompe."

In regard to the etymology of the word, Grignon ("Memoirs de Physique sur l'art de fabriquer le fer, d'en fondre et forger des Canons d'artillerie, &c.") states that the trompe received its name from the fancied resemblance to a water spout. Landais derives trombe (of which trompe is the old French form) from στρόμβος, a top, a spindle, a round shell, which in its turn is derived from στρόφω, to turn, twist, revolve. The author conceives that the trompe received the same name as water spout, "either because of the mixed column of air and water produced in certain forms of the machine, or more probably from the whirling motion of the water around a conical cavity," which would occur in many of the old forms of the trompe; in both these respects there is a resemblance to a water spout.

The second section of the paper is devoted to the description of an instrument by means of which the amount of air carried down by a stream under various conditions can be determined with accuracy. Several tables of experiments made with this instrument are given, which show the amount of air carried down by half a litre of water, under various conditions of pressure, velocity, &c., and flowing from *a*, a circular, *b* rectangular, *c* square, and *d* triangular discharge tube. The constituent of a jet of liquid moving downwards with great velocity is considered, and it is stated that when such a stream falls through a vertical tube, the area of the cross section of which does not exceed a certain dimension in relation to that of the orifice from which the liquid flows, disks of water are produced in the tube, which are pushed down by the descending stream, and force down the air beneath them.

If, on the other hand, the pressure on the lower orifice of the vertical tube is competent to support a column of water at a certain height in the tube, the descending stream comes into direct collision with the water, and air is then carried beneath the water surface on account of the formation (by the descending masses of water) of cavities, into which air enters, according to the theory of Professor Magnus, of Berlin.

The author gives the following example to illustrate this mode by which air is carried beneath the surface of the liquid :—" We have a frequent example of this action of detached fluid masses. If we wish to pour out beer so that it shall have no froth, we pour it down the side of the glass, the adhesion of which flattens the stream into a ribbon, and it enters the fluid in the glass slowly. There is no falling of detached masses here, consequently no air is carried down. On the other hand, if we wish to produce froth, we pour out the beer from as great a height as possible, and the masses detached by the accelerating force of gravity carve out channels in the liquid, into which air enters and is carried down, and afterwards rises to the surface in bubbles."

A small lead shot weighing ·072 gramme was found to cause 192 times its own volume of air to penetrate beneath the surface of water by being thrown into it for a height of $1\frac{1}{2}$ feet at an angle of 60°.

The greatest amount of air which the author found to be carried down by a stream of water flowing from a delivery tube 3-20ths of an inch diameter through a vertical tube 21-60ths of an inch diameter at the rate of half a litre in 34 sec. was—*a*, by disk action, 615 c.c.; *b*, by direct collision, 182 c.c. per half litre of water.

We have all noticed the whirling conical cavity which forms over an orifice in the bottom of a vessel from which a liquid is escaping. If rotatory motion is given to the liquid before it commences to flow, the cavity forms at a considerable height about the orifice, and air enters through it and makes its way into the issuing stream. This is discussed in the third section of the paper. The author found more air to be carried down by this means than by any other. Water flowing from a tube 13-120ths of an inch diameter at the rate of half a litre in 39 seconds, carried down no less than 1392 c.c. for each half litre of water. " Stated in other words, a little stream of water about 1-10th of an inch in diameter at the orifice from which it issues, with a head of water of two feet, carries down in one hour 128 litres of air."

Let us suppose a continuous vertical tube less than 33 feet long in connexion with a water cistern, and moreover that water is flowing through the tube into a vessel containing water ; if we close the orifice in the cistern from which the water issues, a column of water will remain suspended in the vertical tube by atmospheric pressure. Now let an orifice be made anywhere in the circumference of the tube, and the column of water beneath that orifice will immediately fall, because the atmospheric pressure below the orifice is at once neutralized, and the water descends by its own weight. If we again cause water to flow through the tube, the column below the lateral orifice will obviously have greater velocity than that above it; hence rupture will ensue at the orifice, and air will enter, the flowing water will momentarily close the orifice, air will again enter, and so on.

The fourth section of the paper, is devoted to the carrying down of air by this mode, and the author found that half a litre of water flowing from a delivery tube 3-20ths of an inch diameter carried down 320 c.c. of air.

In the fifth section Mr. Rodwell gives a summary of the investigation; this we give verbatim:—

" We see from the above that there are four modes by which air can be carried down by a stream of water falling through a tube.

"1. If the area of the cross section of the tube through which the water falls be not much greater than that of the orifice from which the water flows, disks will be formed in the tube, and being pushed down by the descending stream, will force down the air beneath them.

" 2. If the area of the cross section of the tube through which the water falls, be much greater than that of the orifice from which the water flows, so that disk action is prevented : or if the pressure on the lower end of the tube be competent to support a column of water in the tube at such a distance from the orifice from which the water flows that the descending stream has not widened sufficiently to allow of the formation of disks, air will be carried beneath the water surface on account of the formation of cavities, according to the theory of Magnus.

" 3. If there is not a great depth of water in the vessel which supplies the descending stream, or if (the depth not of necessity being small) rotatory motion from any cause imparted to the water, air will enter through a cavity formed above the orifice from which the descending stream issues, and extending into the descending stream.

" 4. If the area of the cross section of the orifice from which the water flows be as great, or nearly as great, as that of the tube through which the water falls, and if at the same time the orifices for the admission of air do not exceed a certain area compared with that of the orifice from which the water flows, air will enter at the rupture of the steam, produced at the orifices, by the accelerated motion of the water below those orifices.

" The cause of the descent of air in the different modifications of the trompe is not due to any one action of a stream of water; air is carried down by all four of the modes of action mentioned above.

" Generally only one mode obtains in one form of the machine ; but there may be two modes acting simultaneously, the particular mode or modes being determined, *a*, by the relation of the area of the cross section of the trompe tube to that of the orifice from which the stream flows ; *b*, by the head of water above the orifice from which the stream flows; *c*, by the fact of whether there are causes which induce rotatory motion in the water before it leaves the cistern ; *d*, by the form of the orifice from which the stream flows ; *e*, by the manner in which air is allowed access to the interior of the tube ; and lastly, *f*, by the amount of pressure on the lower orifice of the tube.

"The first and fourth modes least seldom obtain; the second obtains in the generality of modern trompes; and the third obtains in the trompe described by François, in trompes with very shallow cisterns, in trompes in which water before leaving the cistern receives rotatory motion, either from the stream which supplies the cistern entering at an angle to the water surface, or from some other cause, and in all trompes with inclined tubes (of which, as above stated, Kircher had seen forty prior to the year 1655).

"I consider the most economical, and in every way the most efficient form of trompe, to be the old form, in which there are no air-holes, and the air enters by a conical cavity in the water above the orifice from which the descending stream issues. It will be seen from the above that by this method we obtain nearly double the amount of air obtainable by other means. The construction of such a trompe, moreover, is comparatively easy; there is no need to have the tubes perfectly vertical, and less spray is carried into the furnace than by the form of trompe now in use."

On Chemistry Applied to the Arts. By Dr. F. Crace Calvert, F.R.S., F.C.S.

From the London Chemical News, No. 241.

Continued from page 256.

Gelatine, Glue, Bone-size, Chondrine, their preparation, chemical properties, nutritive value, and application to arts and manufactures. Artificial tortoise-shell. *Isinglass*, its adulterations and adaptations to the clarification of fluids. *Skins* and the art of tanning.

Lecture II.

Delivered on Thursday evening, April 7, 1864.

As the syllabus will show you, I intend to draw your attention, especially in this lecture, to gelatinous substances, as well as to the art of tanning. There are four distinct gelatinous substances obtained on a commercial scale from animal tissues and bones, viz:—*Osséine*, which I mentioned in my last lecture, *Gelatine*, *Chondrine*, and *Isinglass*.

Osséine, as already stated, is the animal matter existing in bones, and no doubt it is the same substance which also exists in skins, both during life and when recently removed from the animal. It is characterized by its insolubility, its inability to combine with tannin, and lastly, the facility with which it undergoes a molecular change, and becomes converted into gelatine, slowly, when boiled with water at 212°, rapidly, when boiled under a pressure at a higher temperature, and very gradually under the influence of putrefaction.

Gelatine is a solid semi-transparent substance, which absorbs water in large quantities (40 per cent.), becoming thereby transparent. It is very slightly soluble in cold water, but very soluble in boiling water, and this solution has the characteristic property of forming a jelly on cooling. So powerful is gelatine in solidifying water, that one part of gelatine will form a jelly with 100 parts of water. It has been observed that gelatine loses this valuable property if boiled for a lon time at ordinary pressure, or if carried to a temperature above 223° F. Before examining the interesting action of acids upon gelatine, allow me to mention that whilst solid gelatine resists putrefaction for a long time, its solutions have a tendency to putrefy rapidly, but I have the pleasure to inform you that a few drops of a substance called carbolic acid will prevent putrefaction for a long period. Gelatine dissolves rapidly in acetic acid, of moderate strength, or vinegar, and this solution, which is used as glue, has the useful property of remaining fluid and sound for some time. But a Frenchman, named Demoulin, has introduced of late years in Paris a solution of glue which is superior to the above and to that in common use, because it does away with the trouble of constantly heating the glue-pot. His process consists in melting one pound of best glue in one pound of water, and adding gradually to the two one ounce of nitric acid of sp. gr. 1·36, heating the whole for a short time, when the fluid glue is prepared. The action of concentrated nitric acid on gelatine is most violent, giving rise to several compounds, amongst which may be cited oxalic acid. The action of sulphuric acid on gelatine is important in a scientific point of view, as an alkaloid called leucine is produced, as well as a sweet substance, called glycocolle, or sugar of gelatine. Gelatine is distinguished from other organic substances by the following chemical reactions:—it gives a white precipitate with alcohol, also with chlorine, none with gallic acid, but one with tannin, or tannic acid. The properties of this precipitate are most important to us, as it is on the formation of it in hides that we ascribe their conversion into leather. The relative proportion of these two substances (gelatine and tannin) in the precipitate varies with the respective proportions brought in contact, but precipitates containing as much as 46 per cent. of tannin have been examined. It is insoluble in water, and presents the invaluable character of not entering into putrefaction. Beautiful fancy ornaments have recently been introduced in Paris by M. Pinson, called artificial tortoise-shell, which he obtains by melting at a moderate temperature, gelatine with a small amount of metallic salts, running the whole into moulds, staining the mass with hydro-sulphate of ammonia, so as to produce an imitation of the grain of tortoise-shell. The objects so produced are then polished and ready for sale. Before entering on the manufacture of various qualities of gelatine, I should wish to state that there can be no doubt, from the researches of Magendie, as well as from the Report of the Commission appointed by the Netherlands Academy of Sciences that gelatine as food possesses no nutritive value whatever. Allow me now to give you a rapid outline of the methods followed in the manufacture of various qualities of gelatine. The first quality of gelatine is prepared by taking the clippings, scrapings, and fleshings from the tanyard, treating them with lime water or alkali, to remove any smell and certain impurities. They are then well washed and left in contact for a day or two with a solution of sulphurous acid. They are then placed in a suitable apparatus with water, and heated, when the osséine is converted into gelatine. This is run into a second vessel, and a little alum added, to throw down any impurities that may be in suspension. The liquor is now ready to be run into another pan, where it is concentrated to the necessary consistency, so as to become solid when it is run into wooden moulds. Eighteen hours afterwards the gelatine is turned out of these moulds on to a wet slab, where it is cut into slices by means of a copper wire; these slices are placed on wire gauze frames, and left in a drying shed until they are perfectly dry and ready for the requirements of trade. The second quality of gelatine is prepared by placing bones in large cylinders, and allowing high-pressure steam to arrive at the bottom of the cylinder, which rapidly converts the osséine of the bones into gelatine, and the removal of this is facilitated by allowing a stream of hot water to enter the upper part of the cylinder. The solution of gelatine thus obtained is evaporated, and is usually employed for the preparation of glue. A third quality is prepared by treating bones with hydrochloric acid (as referred to in my first lecture), and submitting the osséine thus obtained to the action of steam. Lastly, a fourth quality of gelatine, called bone-size, is manufactured by boiling more or less decayed bones, as imported from South America and elsewhere, the flesh of dead animals, &c., and concentrating the solution to the consistency required for the various applications it receives in commerce. [The lecturer then described the mode of obtaining the beautiful thin colored sheets of gelatine used in photography and other fancy purposes, and also the characteristics which distinguished good from bad glues.]

Chondrine, or cartilage gelatine, first noticed by Messrs. Müller and Vögel, jun., is interesting as possessing qualities, not only different from those of gelatine, but such as injure the quality of the latter when mixed with it. In fact, it gives precipitates with acetic acid, alum, persulphate of iron, and other salts; and as gelatine is often used in connexion with these substances, it is easy to foresee how these precipitates may interfere with its application. On the other hand, the quality possessed by this peculiar gelatine, may, I think, render it serviceable in the art of calico printing, for fixing colors, or as a substitute for albumen or lactarine. Thus, the solution of chondrine and acetic acid may be mixed with any of the new tar colors, and the whole printed, allowed to dry, and steamed; the acetic acid will be driven off, leaving the color fixed by the chondrine on the fabric. Chondrine is prepared by submitting to the action of heat and water the cartilaginous tissue of animals, or the bones of young animals.

Isinglass is obtained from the air-bag or swimming-bladder of several kinds of fish, especially those of the sturgeon tribe, and, although imported from various parts of the world, the principal supplies are from Russia, from whence the best qualities come, which bear the names of Beluga, Volga, or Caspian Sea leaf. Brazil, New York, the East Indies, and Hudson's Bay also supply various qualities of this valuable substance. It also reaches this country in different states, viz: in leaf and in honey-comb, that is, the bag is cut open, cleaned and dried; and the quality called snow-bleached is enhanced in value by having been buried in the snow on the banks of the Volga for a long period, by which the isinglass is whitened. Pipes, purses, and lumps are bags which have been cleared but not opened; and a quality called ribbons is made by rolling the bag and cutting it into strips before shipping it to this country.

I shall now endeavor to explain to you how the beautiful preparations before you, for which I am indebted to the kindness of Mr. Jas. Vickers, are obtained. The leaf bladder is first softened in water, and rolled out, under high pressure, into thin leaves, which may extend to several feet long; these in their turn are drawn under a number of revolving knives, making 1000 revolutions per minute, by which 6000 of the well known fine threads are produced in every minute. This quality is chiefly used for culinary purposes. For commercial uses the purses or lumps above mentioned are chiefly employed. These are soaked in water for two or three days, cut open, certain useless parts removed, further softened, rolled and cut into various dimensions, according to the requirements of trade, their chief use being the clarification of beer and other alcoholic fluids for which gelatine cannot be employed, because it dissolves in water, whilst isinglass merely swells. The result is that the highly swollen and extended mass, when poured into beer, wine, or other alcoholic fluids, is on the one hand contracted by their alcohol, and on the other hand it combines with their tannin, forming an insoluble precipitate, which, as it falls through the liquor, carries with it the impurities in suspension, and thus clarifies the fluid. As isinglass is very slow in swelling out in water, brewers employ an acid fluid for the purpose, but, strange to say, instead of using pure acetic acid, many of them take sour beer, and thus run the great risk of spoiling their sound beer. I have known instances of great losses occurring in this way, acetous fermentation having been thus spread through an entire brewery during the summer months. As a large quantity of gelatine, cut into shreds, in imitation of isinglass, is sold at the present day, it may be useful to know that detection is very easy by the following method:—Place a small quantity in hot water, in which gelatine will readily dissolve, whilst isinglass will do so very slowly. I cannot conclude the examination of this interesting class of substances without drawing your attention to the fact that osséine, gelatine, chondrine, and isinglass present marked differences in their textures and general properties, although their chemical compositions may be considered identical, thus:—

	Osséine.	Gelatine.	Chondrine.	Isinglass.
Carbon, .	50·4	50·0	50·61	50·56
Hydrogen, .	6·5	6·5	6·58	6·90
Nitrogen, .	16·9	17·5	15·44	17·79
Oxygen, .	26·2	26 0	27·37	24·75

Esculent Nests.—I must not omit to mention, in connexion with this interesting class of substances, these curious gelatinous products, which are not only considered great delicacies in China, India, but even in Europe, where they realize from £3 to £7 per pound; considerable quantities are imported into England. It has long been a disputed question what is the chemical nature of the substances composing these nests, which are the product of a peculiar kind of swallow; but Mr. Payen, by his recent researches, has left no doubt in the minds of chemists that it is an animal, not a vegetable matter. In fact, it is a peculiar mucous substance, secreted by the bird, and composed of carbon, hydrogen, oxygen, nitrogen, and sulphur. Further, it is insoluble in cold water, but soluble in boiling, and differs from gelatine and isinglass in that it does not gelatinize as it cools.

Skins.—Skin consists of two principal parts, one a mere film, called the epidermis, and the other constituting the bulk of the skin, and called the dermis. There are also found in skin a large quantity of blood-vessels, and a small quantity of pigment cells, which hold the coloring matter. Further, the skin contains a small amount of nerves and a number of glands, among which may be cited the sebaceous glands or follicles, which are intended to secrete the unctuous matter constantly accumulating upon the skin, and keeping it soft and pliable; then there are the perspiratory glands, which play a most important part in the physiological construction of the skin. These are so numerous that Mr. Erasmus Wilson has calculated that there are 3528 of them in a single square inch of human skin, so that in an ordinary sized body there are no less than 2,300,000 of these pores. But still the most important part of the hide for us is that called the "dermis." The skins of animals are commercially divided into three distinct classes. The hide is the name given to the skin of full-grown animals, such as oxen, horses, and buffaloes; and these are further sub-divided into fresh hides, that is to say, those which are obtained from animals slaughtered in this country; dry hides, that is, hides which have been dried in the sun, and which are principally imported from South America; dry salted hides, principally from the Brazils, where they are salted and then dried in the sun; and salted hides, which are preserved in Monte Video and Buenos Ayres by salting them, and which are shipped, embedded in salt, to this country. The composition of a fresh hide may be considered to be as follows:

Real Skin, ...	32·53
Albumen, ...	1·54
Animal matters soluble in alcohol, . .	0·83
Animal matters soluble in cold water, .	7·60
Water, ...	57·50
	100·00

A second class of hides is that called kips, which are skins flayed from the same kinds of animal as the foregoing, only when young. Thirdly, the term skin is applied to those of small animals, such as the sheep, goat, seal, &c.

I will now endeavor to give you an idea of the preparation which hides undergo to fit them for the art of tanning. These operations are four. The first consists in washing off the dirt from the hide, softening it, if a dried one, or removing the salt, if salted. The second has for its object the removal of the hair, which is effected by two or three different methods. The most usual plan is to place the hides in large vats, containing a weak milk of lime, for two or three weeks, care being taken to remove and replace them every other day, after which time the hair is sufficiently loosened to be removed. A second plan consists in piling up the hides, allowing them to enter slightly into a state of putrefaction, and then placing them in weak milk of lime, so as to complete not only the loosening of the hair, but also the swelling of the hide, for lime also possesses that property. Another process, called the American plan, is to hang the hides in pits for two or three weeks, keeping them at a temperature of 60°, and constantly wet, when the hair can be easily removed. Weak alkalies are sometimes substituted with great advantage for lime in the above processes, and this plan is certainly the best, as it does not leave in the hide any mineral residue, as is the case with lime, either in the form of an insoluble soap of lime or of carbonate, both of which are highly objectionable in the subsequent process of tanning, as they act on the tannic acid of the tan, facilitating its oxidation, and thereby rendering it useless. Depilation of hides is sometimes effected by the employment of weak organic acids; thus, the Calmuck Tartars have used from time immemorial sour milk for that purpose. In some parts of France, Belgium, and Germany, the unhairing of the skins is also effected by an acid fluid, produced by the fermentation of barley meal, which gives rise to acetic and lactic acids. To carry out this process, generally speaking, five vats are used. In the first the hides are cleaned; in the second they are softened, and the hair and the epidermis prepared for depilation; and the third, fourth, and fifth are used to swell and give body to the hide. This operation, which is called white-dressing, does not work so well as lime for heavy hides, as it swells them to such an extent as to render them unfit to prepare compact leather. When the hair can be easily pulled off, the hides are placed on a convex board called a beam, and scraped with a double-handed concave knife, which not only removes the hair, but a large amount of fatty lime-soap and other impurities from the hides. The third operation consists in fleshing the hides, by shaving off all useless flesh, fat, and other matter by means of a sharp tool. The fourth operation is called swelling or raising the hide, the purpose of which is the following: First, the removal of any lime or alkali which may remain in the hide; and secondly, to swell or open the pores of the hide, so as to render them better adapted to absorb the tannic acid of the tanning liquors. This is effected by dipping the hides in weak spent tanning liquors, or liquors which have lost their tannic acid, but which contain more or less of gallic acid, for not only do all tanning matters contain gallic acid, but its proportion is greatly increased during the operation of tanning, by a process of fermentation which goes on during that operation, and which converts tannic acid into gallic acid and a peculiar sugar.

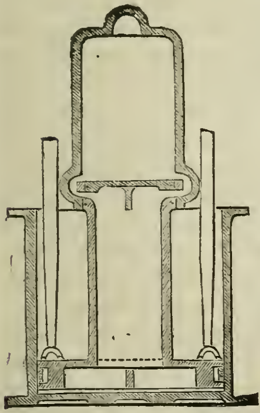
The Tanning of Hides.—The old process of tanning consisted in placing layers of wet tan and of hides alternately, and after two or three months removing the whole from the pit and replacing the old by fresh tan. These operations were repeated until the hides were tanned, which took from eighteen months to two years, owing to the difficulty of the tannic acid reaching the interior of the hide. Of late years the process of tanning has been greatly shortened by treating the bark with water, and steeping the hides in the liquor, first weak and afterwards strong. By this means good leather can be obtained in the space of eight or ten months. More rapid tanning, but probably giving inferior leather, is effected by employing, in conjunction with, or as a substitute for, bark, a decoction of dividivi, valonia, myrobalan, catechu or terra japonica, gambir, &c. Many efforts have been made of late years to apply the laws of hydraulics, as well as several physical and physiological principles discovered by eminent philosophers, with the view of shortening the period of tanning, but as I believe that none of them have received the general sanction of the trade, I shall confine myself to giving you an idea of the most successful ones. The first attempt to accelerate the process of tanning consisted in forcing the tannin fluids into the substance of the hide by means of hydraulic pressure. Mr. Spilbury, in 1831, employed a process which consisted in making the hides into sacks, and plunging them into a tanning liquor, and as the fluid percolated through the skin into the interior of the bag the air was allowed to escape. By this means a certain amount of time was saved in bringing the tanning liquor in contact with the various parts of the skin. Mr. Drake soon followed in the same direction, his plan being to sew hides together, forming bags, which he filled with a solution of tan ; and to prevent the distention of the skins by the pressure of the liquid within, they were supported in suitable frames ; as the pores became gradually filled with tannin, artificial heat was applied to increase the percolation of the fluid. Messrs. Chaplin and Cox's process is also very similar to the above, the difference being that the tannin fluid is placed in a reservoir, and allowed to flow into the bag of hides through a pipe, the fluid being thus employed at pressures varying according to the height of the reservoir. The bag of hides is at the same time plunged into a solution of tannin to prevent excessive distension. Messrs. Knowles and Dewsbury have recourse to another principal to compel the percolation of the tannin liquor through the hide. To effect their purpose they cover vessels with hides, so as to form air-tight enclosures, and, having placed the tannin fluid they employ on the hides, the vessels are exhausted of air, and atmospheric pressure then forces the fluid through the skins into the vessels below. Mr. Turnbull's process, being an imitation of that used for tanning Morocco leather, need not be described. Attempts have been made from time to time to mineralize hides, that is to say, to substitute for tanning, mineral salts, as will be described in my next lecture, when speaking of the art of tawing skins. The processes which have attracted most notice in this branch of the art of preparing leather are those of Messrs. D'Arcet and Ashton, M. Bordier, and M. Cavalier. M. Bordier's plan is that of dipping hides in a solution of sesquisulphate of iron, when the animal matters of the hide gradually combine with a basic sesquisulphate of iron, rendering the hide imputrescible, and converting it into leather. M. Cavalier's method is to dip hides first into a solution of protosulphate of iron, and then into one containing alum and bichromate of potash. A chemical action ensues, by which the protosulphate of iron is converted into a persulphate, combining with the animal matter, and by its preservative action, together with that of some of the alum, the hide is converted into leather. I think, however, that I shall be able to satisfy you, from the results of many examinations of leather and hides which I have made, that there are good and sufficient reasons why most of these processes have necessarily failed. Inventors have been led to believe, by the statements of many eminent physiologists, (as can be proved by reading some of the most recent works on that science), that skin is composed of blood-vessels, glands, &c., plus gelatine, and that if by any mechanical contrivance the tanning liquor could be brought into contact with this gelatine, the leather would be tanned; and many ingenious schemes have been devised, and much money expended, to obtain that result. The fact, however, is that there is no gelatine in skin, for if there were, when hides were placed in water, the gelatine would be dissolved and washed away. But what is supposed to be gelatine in the hides is in reality the isomeric substance called osséine, or one greatly resembling it. The great discovery to be made in the art of tanning, therefore, is that of a chemical or fermentative process, by which the isomeric change (that of the osséine into gelatine) may be rapidly produced, instead of by the slow putrefactive process which occurs in the old method of tanning. Further, I would observe that to convert a hide into leather it is not sufficient that the whole of its animal matter be combined with tannin, for the leather thus obtained would present two great defects; 1st, the hide would not have increased in weight, and the tanner's profits, therefore, would suffer; 2dly, the leather would be so porous as to be useless for many of the purposes for which leather is required. The reason of this is, that when, after a period of several months, the osséine has been converted into gelatine, and this has become thoroughly combined with tannin, a second series of reactions is necessary to render the leather more solid and less permeable to water, and to increase materially its weight. These reactions constitute what is called feeding the hide, and are brought about by leaving it to steep in more concentrated tanning liquor for a considerable period; and this necessary process, beneficial to the wearer as well as to the producer, appears to me to be that which offers the greatest impediment in the way of shortening the period of tanning. The hides as they leave the tanning vat require several operations before they are ready to be used for soles, or to be curried for various commercial purposes. They are first slightly washed and placed in a shed to partially dry, and are then rubbed with a brush and rough stone on the face of the leather, or hair side, to remove any loose tanning material that may remain on the surface; but this rubbing is not applied to the back, as buyers attach great importance to the peculiar appearance called the bloom, which enables them to judge of the goodness of the tanning. The tanned hides are again slightly dried, and oiled on the face, and then submitted to the pressure of a roller passed over the surface, which has the effect of rendering the leather more flexible, and the surface perfectly uniform. These operations are repeated two or three times, when the leather is ready for soles. Before the tanned hides intended for shoe-soles are considered fit for that purpose, they must be slightly compressed and softened, so as to again diminish their permeability to water. This was formerly effected by beating with a hammer called the mace, but of late years this slow process has been superseded by compressing machines; and I believe those most appreciated in the trade were invented by Messrs. Cox and Welsh, and Messrs. Iran and Schloss.

To be Continued.

Lake's Differential Steam Engine. By Francis Campin, C. E.

From the London Artizan, March, 1865.

Sir:—In the differential steam engine, of which the annexed diagram exhibits a vertical section, great simplicity of construction is achieved, in addition to increased economy in consumption of steam. The engine comprises two cylinders of different diameter, so arranged as to be axially in the same straight line; these cylinders are furnished with pistons, as shown in the sketch, that in the small cylinder being perforated round its periphery between the packing rings. The interior of the piston communicates with a trunk or chamber which connects it to the large piston in the expansion cylinder, which is open at the bottom. When the small piston is at the bottom of the stroke, as illustrated, the holes in its periphery correspond to others in the curved lateral steam passages, of which the other ends open into the cylinder a little higher up, and through which steam from above the small piston flows, filling the trunk and space below the large or expansion piston.



Let us now examine the effect of the working of the engine, assuming the following dimensions: Diameter of small cylinder 8 ins.; of large cylinder 16 ins.; stroke 1 foot; cubic contents of trunk equal those of the small cylinder; pressure of steam above the atmosphere, 60 lbs. per square inch, or absolute pressure, 75 lbs. per square inch.

The effective area of the small piston may be taken as 50 square inches; that of the large piston being four times as much, or 200 square inches. First we will consider the work done in the down stroke through which the steam acts on the small piston with its full force: we have 50 square inches × 75 lbs. per square inch × 1 foot = 3750 foot lbs.; the useless resistance is the atmospheric pressure, or 50 square ins. × 15 lbs. × 1 foot = 750 foot lbs., which, deducted from the gross work, leaves as effective work 3000 foot lbs. done during the down stroke. In the up or expansion stroke, the steam supply is cut off as soon as the small piston has repassed the ends of the lateral steam passages, and then the steam in the trunk continues to expand during the remainder of the stroke; and because the large cylinder is four times the size of the trunk, (of which the contents equal those of the small cylinder,) it is evident the steam will expand five times, or down to a pressure of 15 lbs per sq. inch absolute; for that quantity of steam which at the commencement of the stroke filled only the trunk, will, at the end of the same stroke, fill the trunk, and in addition thereto the large cylinder. The mean pressure in the up stroke will therefore be about 45 lbs. per square inch; so the gross work done by the steam in the up stroke will be 200 square ins. × 45 lbs. × 1 foot = 9000 foot lbs. From this must be deducted the prejudicial resistances: first, there is the whole pressure of steam on the small piston (for the small cylinder is always in communication with the boiler; this represents 3750 foot lbs. work in the stroke. There is also the atmospheric pressure on the top of the annular part of the large piston,—150 sq. ins. × 15 lbs. × 1 foot = 2250 foot lbs., making the total prejudicial resistances 6000 foot lbs. in the up stroke, leaving for effective work 9000—6000 = 3000 foot lbs., exactly the same as in the down stroke. Thus in one revolution of the engine 6000 foot lbs. of work would be done. As soon as the steam in the large cylinder has expanded down to 15 lbs. per square inch, a self-acting valve in the exhaust passage which has hitherto been kept closed by the pressure of steam against it, falls open of its own weight, or by pressure of a light spring; so the steam escapes from under the large piston, and another down stroke is made, at the end of which the closing of the exhaust valve is produced by the pressure of the steam admitted to the large cylinder, or by a tappet. At the end of the up stroke the steam is not all discharged from the large cylinder, as the trunk will remain full at atmospheric pressure; so the steam actually used for each double stroke of the engine will be only four-fifths of a trunk full, or 0·28 cubic feet. If we suppose the engine to be running at 35 revolutions per minute, 588 cubic feet of steam per hour will be used, or 92 cubic feet per horse power per hour, (the power, in the instance cited, being 6·39 horses.) This, at 75 lbs. absolute pressure per square inch, is generated from 15 lbs. of water per hour, with a consumption of 21 lbs. of coal—hence the consumption of fuel will be but 2 lbs. of coal per indicated horse power per hour, corresponding to a duty of 110,000,000 foot lbs. per 112 lbs. of coals consumed. Comparing this with the Cornish engines, we find the results favorable to the differential engine; for of the 34 engines reported in Cornwall for September, 1864, the average duty was but 49,800,000 foot lbs., and even the highest duty was only 70,800,000 foot lbs.; and the greatest economy yet attained by any Cornish engine over long periods of working was not more than 109,000,000 foot lbs. per 112 lbs. of Newcastle coal consumed.

It may be further remarked that in the manufacture of the differential engine comparatively little labor would be required, as there is scarcely any fitting about it, and there is but one valve (that being self-acting), and no glands nor eccentrics.

The Surface Condenser Superseded. *

From the London Mechanics' Magazine, February, 1865.

A fulfilment of the title of this work would mean little less than a revolution in marine engineering. The important function intended to be carried out by the surface condenser—that of saving the fuel now lost in blowing off and in the formation of incrustations on the heating surfaces—can scarcely be said to be achieved without many counterbalancing drawbacks. It was thus with some amount of *empressement* that we have opened the work before us with a view to see how it answered to its title. We may as well at once say that the matter inside very well bears out the promise on its title-page. M. Emile Martin certainly explains himself with remarkable clearness and precision, and he is also generally very careful to back up his assertions with facts and proofs which leave as little doubt as possible in the minds of his readers.

To give a brief idea of the substitute for the surface condenser, we may say that M. Emile Martin uses superheated steam in order to raise the temperature of the feed water. This is with the object of separating the salts held in solution, which would otherwise form incrustations in the boiler. Exhaust and saturated steam have been long used with more or less success on the continent for the same purposes, but the efficiency of these plans has been lessened from their comparatively limited heating powers. M. E. Martin has thus had the very simple and yet extremely happy idea of previously superheating the steam he uses as the agency for precipitating the salts contained in sea and other waters. In thus increasing the efficiency of a previously known form of feed water heater, he raises it to the level of the importance of the expensive surface condenser. Instead of directly introducing the feed water into the boiler, it is injected in the form of a fine shower, through a rose, into a casing filled with saturated steam. This steam is fed from the boiler itself. The water, by its contact with the steam, rapidly acquires a high temperature, which is additionally raised by means of a current of superheated steam entering the apparatus in a contrary direction to the water. This water is at last changed into steam, leaving all its incrustations on perforated plates contained in the vessel. The steam generated in the vessel then flows into the steam room of the boiler, while the water, which is considerably heated, is conducted by means of a pipe into the bottom of the boiler. Steam can be taken from any source as long as it possesses, at its entry into the vessel, a pressure at least equal to that in the boiler which has to be fed. Nevertheless, in order to obtain the utmost amount of economy, it is indispensable that the steam which is to be superheated be drawn from the boiler itself. The invention will be found illustrated and described at page 174 of our last volume in the number for September 9th, 1864.

The efficiency of this arrangement is very evident, because, in a small and compact apparatus, it is possible to raise the water to such a temperature that it can deposit all its incrustation. In fact, the steam fed from the boiler and superheated at the expense of heat which might otherwise be lost, becomes a powerful agent, giving out all its caloric in the purifying vessel. The same results could not be obtained either from exhaust or even saturated steam. Many facts cited in his work corroborate the assertions of the author, and as far as regards the purification of the water, we cannot but think very highly of the invention.

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* "Le Substituant du Condenser á Surface, nouvelle Application de la Vaper Surchauffee," par Emile Martin. Londres; Barthes and Lowell, 1865.

But then comes the question: Is M. Emile Martin's apparatus really a substitute for the surface condenser? There can be no doubt that it is a substitute for it in so far, and in so far only, as the surface condenser is a water purifier. Of course, Mons. Martin could never intend to supersede, by means of a water purifier, the ordinary condenser and air-pump. He merely takes the ordinary Watt's condenser and adds to it an apparatus that allows it to perform the functions of the new-fangled and cumbersome surface condenser. But also, in addition to this, the hot water from the apparatus is conveyed and passed into the boiler. As is remarked by Mr. Thomas Halliday, M. Emile Martin's apparatus, if well applied, will, with an ordinary condenser, allow an engine to effect as much economy as if furnished with a surface condenser. An ordinary marine engine generally gives out one indicated horse-power by the consumption of from 3½ to 4 pounds of good Welsh coal per hour. An engine furnished with surface condensers affords an indicated horse-power by the consumption of 2½ to 2¾ pounds of coal per hour. Mr. Halliday thus fairly estimates the loss of heat through blowing off at 33 per cent.; all of which can be saved by means of an efficient apparatus for initially getting rid of the salts that require blowing off and that led to incrustation. *En resumé*, this apparatus seems, from the great practical advantages it offers, of very great importance, and we hope to return to the principles that it involves.

In the second part of M. Emile Martin's work, we find some really interesting details on the applications of his improved steam generating apparatus. The leading idea of this invention consists in using two fire-places, and, therefore, double firing. From the upper part of each, tubular flues rise up to a hollow chamber within the boiler. From this chamber descend one or more flues, at whose lower portion is a perforated grating of fire-clay, on which there is constantly kept a quantity of incandescent fuel. Below this is a space communicating with a chimney, into which the products of combustion are exhausted by means of a fan or by any other plan for producing a draught. In order to try the plan, the Great Eastern Railway Company has already applied it to an old locomotive now working as a stationary engine at the Stratford station. This old boiler, furnished with M. Emile Martin's apparatus, is able to provide with steam an engine of one hundred horse-power, and with an economy of 33 to 40 per cent. over the fifty-horse boilers built up close by. These boilers are still in a very good state, and the advantage over them obtained by the old locomotive boiler furnished with this apparatus, seems mainly due to the consumption of smoke obtained by the latter. In this work is also contained a report from two engineers addressed to Mr. Sinclair, the locomotive superintendent of the Great Eastern Railway, showing that by means of this arrangement, 10 pounds of water were evaporated by the use of only one pound of fuel, exclusive of the fuel used for getting up steam. At page 152 it is observed that Messrs. Kitson and Co., of Leeds, are now constructing a new locomotive on this plan, ordered by the Great Eastern Railway Company, who, as we just stated, have already carefully tried the apparatus. When this locomotive is once on the line, we may be able to allude to its practical performances.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 255.

(Continued from page 200.)

8. *Early Chemistry of the Air.*—From the title of these papers it would naturally be supposed that their object was to give a chemical history of the air, and such was the original intention; but from the fact that many of the experiments of the earlier philosophers are partly physical and partly chemical, and from other causes, I found it impossible to speak of the chemistry of the air alone. I have, therefore, thought it better to give what Mr. Boyle would have called a *physico-chemical* history of the air.

Pneumatics rose to the rank of a science long before chemistry; hence the physical properties of the air were studied before its chemical properties, and hence it follows that the preceding papers have treated of the former rather than of the latter. We have now to consider the early chemistry of the air.

The theory of the mutual convertibility of the four ancient elements was admitted from very early times; it was a tenet in the philosophy of Anaximenes of Miletus, in that of the Stoics, and in that of Aristotle; and it obtained almost universally, either as a whole or in part, till comparatively recent times; we find it admitted in all works on alchemy and chemistry, and in almost all physical treatises published before the 17th century.

As part and parcel of this theory it was believed that water was converted into air by the action of heat, and that air, when submitted to condensation and intense cold, became water.

Among the very few who denied this was Van Helmont,[*] who maintained that if air could be converted into water by condensation and cold it would assuredly become water in very cold weather when condensed in an air-gun; he adds, moreover, that water never becomes air, because if we distil a known weight of water in an alembic we find the same weight in the receiver at the end of the operation, the water being "retorted or struck back"[†] into its own form again.

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[*] Born, 1577. Died, 1644.

[†] *Alembic* is evidently a word of Arabic origin. Chemistry took its rise in Arabia, and the alembic was probably one of the earliest invented chemical vessels: the word *alembicus* frequently occurs in the latin translation of the works of Geber, the first writer on chemistry. The *retort* is a modification of the alembic, and received its name from *retorqueo*, because the liquid which undergoes distillation is *turned back* from the gaseous condition into its original liquid form.

Van Helmont was well aware of the evaporation of water at the ordinary temperature, and it was to distinguish this vapor from steam that he introduced the word *gas* into chemistry. "But because," he writes,* "the water which is brought into a vapor by cold is of another condition than a vapor raised by heat; therefore, by the license of a paradox, for want of a name, I have called that vapor *Gas*, being not far severed from the *chaos* of auntients. In the meantime it is sufficient for me to know that gas is a far more subtile or fine thing than a vapor, mist, or distilled oylinesse, although, as yet, it may be many times thicker than air. But gas itself, materially taken, is water as yet masked with the ferment of composed bodies."

I have invariably seen *gas* derived from the German *geist:* the derivation from *geist* is more plausible than that from *chaos:* nevertheless, the latter, although obscure, is not, I conceive, unintelligible.†

Hesiod, who is supposed to have lived about 900 B. C., is said to have been the first to introduce the idea of the χαος, but it is probable that he borrowed it from Sanchoniatho,‡ the most ancient heathen writer.

The "chaos of the ancients" was conceived to be a confused mixture of elements, from which, when order and harmony were restored by the Creator, the universe was produced. Now, Van Helmont conceived that water is the primal element, from which everything but air and fire is evolved; all substances, animal, vegetable, and mineral, are produced from it and return to it; hence the vapor of water would be a confused mixture of the elements, or, at all events, a something from which all material substance could be produced, and inasmuch as this had hitherto received no name, he determined, from its resemblance to the ancient chaos, to call it *chaos*, which, by an easy change, becomes monosyllabic (chas), and then has almost the sound of *gas*.

From an early age, cupping glasses were caused to draw blood from a patient by placing fire within them to rarefy the air; according to

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* "Oriatrike, or Physick Refined." Written by that most Learned, Famous, Profound and Acute Philosopher and Chemical Physitian, John Baptista Van Helmont, Toparch or Governor in Morede, Royenborch, Oorschot, Pellines, &c. Rendered into English by J. C. (John Chandler), sometime of M. H. Oxon. London, 1662.

† In order that it may be seen that Mr. Chandler's translation has nothing to do with the obscurity of the sentence, I have given the original below from "Johannis Baptistæ Van Helmont Opera Omnia Francofurti," 1707, p. 69. "Progymnasma Meteori," par. 29, in which the sentence stands as follows:—"Verum quia aqua in vaporem, per frigus delata, alterius sortis quam vapor per calorem suscitatus. Ideo paradoxi licentia in nominis egestate halitum illum *gas* vocavi non longè à chao veterum secretum. Sat mihi interim, sciri quod gas vapore, fuligine et stillatis oleo-sitatibus, longe sit subtilius, quamquam multoties aere adhuc densius. Materialiter vero ipsum gas aquam esse fermento concretorum larvatam adhuc." The author of the article on Van Helmont in the "Nouvelle Biographie Générale" writes as follows:—"Lenom de *gaz* ou *gas* (orthographe de Van Helmont) est derivé par corruption de *gahst* *(gaist)* qui signifie *esprit*. Suivant d'autres il derivé de *chaos*, de *blas* (souffle), on de *gaescht* (écume)."

‡ For the account of the Phœnician cosmogony given by Sanchoniatho, see "Ancient Fragments of the Phœnician, Chaldæn, Egyptian, Tyrian, Indian, Persian, and other writers," &c., by J. P. Cory.

Hero, of Alexandria, the fire "*consumes and rarefies*" the air within them, just in the same way that fire consumes and rarefies water and converts it into air. In the time of Francis Bacon, the experiment of burning a candle in a bell jar inverted over water was well known. Bacon denies that air is consumed by the flame, as some imagined; he explains the rise of water into the jar by supposing that as soon as the flame has been "suffocated by the close air," the water rises to occupy the space previously occupied by the flame, in order to prevent the formation of a vacuum. Van Helmont also denied that air is consumed by fire; this arose from the fact of his failing to distinguish between a body capable of supporting combustion, and a combustible body. If air, he argues, is consumed by fire, the whole air would have been inflamed long ago by one single candle, and would have perished. Moreover, if air could be burnt it would become changed, and would cease to be an element, whereas we know it to be a body not compounded of parts, but simple and unalterable.

The calcination of metals was one of the principal operations practised by the alchemists and early chemists; in all their writings we find a prominent place given to a description of this process.

Massicot and minium (PbO and Pb_3O_4) were much used by the ancients. Klaproth found 10 per cent. of oxide of lead in a specimen of red glass from an Egyptian mummy case; and Davy, on analyzing the dark yellow coloring matter of a piece of stucco found in an ancient Roman ruin, proved it to consist of a mixture of minium and protoxide of lead.

Geber, who wrote in the eighth century, was the first to notice that the calx of lead possessed a different weight from that of the lead which produced it. He writes as follows:—[*] "Et licet non multum perfectioni approximet, ex eo tamen per nostrum artificium defacili argentum formamus, *et non servat pondus proprium in transmutatione, sed mutatur in novum pondus.* Et hoc totum in magisterio acquirit. Est etiam plumbum argenti examen in cinericio, cujus causas dicemus."

Cardanus[†] added to this fact by stating, that the gain of weight amounted to *one-thirteenth*[‡] the weight of the lead taken. . . . "Nam plumbum," he writes,[§] "cum in cerusam vertitur, ac uritur, *tertia decima parte sui ponderis augetur.*"

The explanation which Cardanus gives of the cause of the increase of weight is perfectly unintelligible to us, but during the 16th century many theories quite as impossible were brought forward to account for physical phenomena. The lead, he says, during calcination "dies;" the celestial heat which gave it life, and rendered it light, is dissipated, and it consequently becomes heavier, just as animals after death become heavier than before, because their celestial heat has vanished.

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[*] "Gebiri Philosophi ac Alchemistæ Maximi de Alchemia." 1531. Cap. 35. "Sermo in Saturno." Translated into Latin from the original Arabic.

[†] Born, 1501. Died, 1576.

[‡] 100 parts of lead require 7·173 of oxygen for transformotion into PbO; and 9·343 of oxygen for transformation into Pb_3O_4.

[§] "Hieronymi Cardani Medici Medeiolanensis. De Subtilitate." Libri xxi. Parisiis, 1551. Book v. De Mixtione et mixtis imperfectus, sen metallicis."

Cæsulpinus[*] states that lead gains from 8 to 10 per cent. during calcination. "Peculiare huic," he writes,[†] "quod derelictum fertilius reviviscit, crescit enim imbribus; unde chemistæ argumentum sumunt, etiam, aurum, et argentum augeri posse. Sed illud magis admiratione dignum est, *quod ustum in fornace donec cinis fiat, crescit ejus pondus octo aut decem pro singulis centenariis*, ut metallici testantur."

Cæsulpinus attributed the increase of weight to the presence of soot, which he conceived struck against the dome of the furnace in which the calcination was effected, and, being beaten back, fell into the crucible.

9. *John Rey.*—About the year 1628 a M. Le Brun, of Bergerac, calcined 2 lbs. 6 ozs. of tin, and found, on weighing "to ascertain the loss," that the calx weighed 2 lbs. 13 ozs. He next repeated the experiment with the same weight of lead, and found a loss of 6 ozs.[‡] Le Brun mentioned the experiment to several of his friends, but not one of them could give an explanation of the cause of the effects observed, and ultimately he applied to John Rey,[§] an ingenious physician of his acquaintance residing at Bugue, in Perigord.

The subject was investigated by Rey, and the results of his inquiry were published in 1630 at Bazas, a small town in Provence.[||]

Rey's first object was to prove that the air has weight: taking it for granted that bodies cannot descend unless they possess weight, we must admit, he says, that air possesses it, because if we pull a stake out of the ground, air at once rushes in and fills the hole which is left; and however deep we may dig a well, air will descend into it and completely fill it. He mentions, moreover, that if air is compressed in a balloon, the latter, on weighing, will be found to be heavier than before.

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[*] Born, 1519. Died, 1603.

[†] "De metallicis, libri tres: Andrea Cæsulpino auctore." Ad sanciissimum dominum nostrum, Clementum viii. Pont. Max. Romæ. Ex. typographia Aloysii Zannetti 1596. Lib. 3, cap. 7.

[‡] This loss was due to an error of manipulation, arising either from the heat of the furnace being too intense, and too long continued, or from the action of the fused oxide on the crucible.

[§] Born at Bugue in the later part of the 16th century. Died, 1645.

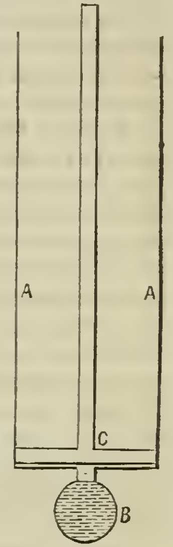
[||] Rey's work is entitled "Essays de Jean Rey," Docteur en Medecine: Sur la recherche de la cause pour laquelle l'estain et la plomb augmentent de poids quandon les calcine." The dedication is to the Duc de Bouillon, and is signed "Rey, au Bugue lieu de ma Naissance dans votre Baronnie de Lymail; le premier jour de Janvier, 1630." The treatise is in the form of twenty-eight short essays, extending over 144 small pages. It is *extremely rare.* A reprint was published in Paris, by M. Gobet in 1777, and a translation by Mr. Children appeared in the 21st, 22d, and 23d volumes of the *Quarterly Journal of the Royal Institution* for 1821 and 1822. I have consulted the original 1630 edition (of which there is an excellent and complete copy in the British Museum Library), and Mr. Children's translation.

The following curious lines by a M. Bereau, are printed at the commencement of the essays:—

"Icyde plus en delaissant,
Des siecles passez la creance,
Vous trouverez l'air se pesant
Qu'on l'examine a la balance.
Vous verrez que cot element,
Se pese en soy par accident,
Vous verrez comme il se r'affine;
Et par un miracle nouveau
Peu s'enfaut qu'il ne se calcine
Par l'effort d'un rouge fourneau."

When certain liquids of different density are mixed together they are afterwards found to separate into distinct layers; so, argues Rey, if a long tube were filled with wine the upper layer would be more spirituous than the lower, and hence he infers that the air on the top of a mountain is less dense than that at its base.

Rey believed that water, by the action of heat, is converted into air, and he describes a method of determining the volume of air produced from a known volume of water. A hollow cylinder of metal, AA, open at one end, has an orifice made in the closed end, into which the beak of a small elopile, B, can be fitted air-tight. A piston, C, moves freely in the cylinder. The piston is forced down to the bottom of the cylinder, and the elopile, filled with water, is then securely fitted into its place. Heat is applied to the elopile until the water it contains is completely converted into vapor, and the height to which the piston is raised is noted. By comparing the capacity of the elopile with that of the cylinder below the piston, the relation of the space occupied by the water to that of the space occupied by the vapor produced from it can obviously be readily determined.



The eleventh of Rey's essays is entitled "L'air est rendu pesant par le separation de ses parties moins pesantes." Just as in distilling wine, a distillate more subtle than wine passes over, and a residue more dense than wine is left in the retort, so, argues Rey, air may be distilled, a "thickened air" being left as residue. We know that air is thickened by the heat of the sun, because soon after sunrise a trembling* of the air is sometimes observed. Now, the air near a furnace also trembles, and is therefore thickened. "For the violence of the fire, subtilizing all the air that comes near it, will drive an immense quantity of it to a distance, leaving around itself of this immense quantity only a kind of dregs, which, from its glutinous weight, cannot fly off."

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* Rey undoubtedly here alludes to the unsteady appearance which objects possess when seen through air having a different density from that around it, an effect due to the alteration of the refractive index of the heated air. It sometimes happens after a very hot day that there are layers of the air possessing different densities, the layer in contact with the soil being heated, and then ascending to make way for colder air. Astronomers are frequently unable to work on account of the unsteady appearance of the objects they view, an effect due to the same cause.

The sixteenth essay is entitled, "Response formelle à le demande pourquoy l'estain, et le plomb augmentent de poids quand on les calcine." "To this question, then," he writes, "resting on the foundations I have laid, I answer *et soustiens glorieusement.* That this increase of weight comes from the air, thickened, and made heavy, and in some degree rendered adhesive in the vessel by the violent and long continued heat of the furnace, which air mixes with the calx (its union being assisted by the continual stirring), and attaches itself to its smallest particles; no otherwise than as water when sand is thrown into it makes it heavier by moistening it and adhering to its smallest grains."

In the eight following essays Rey refutes the opinions of Cardanus and Cæsulpinus, and of several friends of Le Brun, who attributed the increase of weight to the absorption of "the vapors of charcoal," of "the volatile salt of charcoal," of "the volatile mercurial salt," of "moisture attracted by the calx," and of matter removed from the calcining vessel.

In the twenty-fifth essay Rey mentions a single experiment which refutes the opinions of all his adversaries. It will be observed that the above objections are founded on the mode of heating the metal to be calcined. Rey now proves that heat and air alone produce the change.

Hamerus Poppius* mentions an experiment in which he calcined antimony by converging the rays of the sun upon it by a lens. So soon, he writes, as the cone of rays is directed on the antimony, "cum multi fumi profusione calcinabitur . . . et (quod mirabile) licet copiosus fumus multum de antimonio dissipari arguat, tamen antimonii pondus post calcinationem auctum potius quam diminutum deprehenditur." Now, in this instance Rey argues, it is impossible that "the vapors of charcoal," or any of the other volatile bodies supposed to be produced during the calcination in a furnace could have attached themselves to the calx, and yet it was found to weigh more than the antimony which produced it.

Rey next answers the question why a calx does not increase in weight *ad infinitum.* Following up the analogy of sand moistened with water, he replies, may mix sand with sand and water with water in any quantity you please, but this cannot be done with sand and water, for if you add water to sand until it is thoroughly wetted, the sand will take up no more water; it is thus with the calx,—the thickened air attaches itself to its most minute parts, "mais quand tout en assublé, elle n'en sçauroit prendre davantage."

Certain bodies, such as lead and tin, have but little volatile matter, and consequently leave a large quantity of ash to attract the thickened air; while other bodies, such as vegetable and animal substances, have a great deal of volatile matter, and consequently leave but a small quantity of ash to attract the thickened air. In the first instance, the air attracted by the calx weighs more than the matter expelled by heat; in the second instance, the air attracted by the calx weighs less than the matter expelled by heat; hence the former class of substances gain weight during calcination, and the latter lose weight. Such was Rey's explanation of the fact that all bodies do not gain weight during calcination.

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* I am unacquainted with this author, neither can I find his name mentioned in the "Biographie Universelle," the "Nouvelle Biographie Générale," Watt's "Bibliotheca Britannica," nor in the catalogue of the British Museum Library. The quotation given in the text is from a work entitled "Basilica Antimonii Comprobata et Conscripta ab Hamero Poppio Thallino Philochymico," cap. iii. "De calcinatione Antimonii per Radios Solares." This work is printed in the "Praxis Chymiatrica" of Jean Hartmann, published in 1625.

Rey, by careful observation, became convinced that the weight gained by metals during calcination came from the air alone. It was then necessary to construct a theory to show by what means air could produce such an effect. The train of reasoning which induced him to propound the theory given above may be stated in a few words as follows: Air has weight; air most nearly approaches the nature of a liquid, and may therefore be supposed to act like one; liquids may, by the action of heat, be caused to separate into a heavier and a lighter part; therefore air may, by the action of heat, be caused to separate into a heavier and a lighter part; the heavier part approaches more nearly to the nature of a liquid than air; it is the "dregs" of air, and it has changed its fluidity for a "viscid grossness;" this matter attaches itself to the ashes of bodies during calcination as water attaches itself to sand, and renders such of them as possess much ash heavier than they were before calcination.

Rey did not believe that "thickened air" (*l'air espessi*) is the *cause* of calcination. He held to the old theory that calcination is the expulsion by heat of the volatile matter of the body calcined, the calx being the residual ash;—the ash of an organic body was to his mind as much a calx as the oxide of a metal.

The great merit of Rey was, that he regarded air in the light of a ponderable liquid; that which holds good for a liquid, he assumed, holds equally good for air. He thus became able to grapple with an intangible body, and to reason on that which had hitherto from its subtlety eluded the grasp of the philosophers of all previous ages.

Rey's theory was, indeed, fallacious; still, it was a great step in advance of all that had been done in former ages; there is impressed upon it a stamp of a great and energetic intellect. We must not judge of it by what has been done since; we must think of what was done before; we must think of it as the work of a man removed from a great centre of learning; from the converse of scientific men; from every external source of knowledge; compelled to work alone, to think alone. Let it be remembered, moreover, that experimental science had not yet left its cradle; middle age superstition was still very rife; philosophy founded on reasoning had not given way to philosophy founded on experiment; the syllogism had not yielded its place to induction; the Church was still dominant—still condemned all that was contrary to the philosophy of Aristotle, and thus cramped and curbed the human intellect; the "Novum Organum" had but just appeared; and the "Dialoghi" of Galileo were as yet unknown to the world.

Rey lived at the commencement of an epoch, and he was the founder of a branch of scientific inquiry which helped to render that epoch glorious. By energy and perseverence he ascended a lofty eminence, whence he saw in the distance an unknown country—dimly, indeed, and far from him; still it was there, and he pointed out its direction to his fellow-men; but explorers were rare in that day, and men cared not to venture across pathless wastes, to ascend hitherto untrod mountains, in order to arrive at that which, when found, might prove a barren and unproductive country.

Rey's work was but little known during the 147 years which intervened between its publication and its reprint in 1777. It was published in a small and obscure town of Provence, and from the fact that at the time of the reprint it was extremely scarce, it is to be supposed that only a few copies were originally printed. Had it been better known, the theory of Phlogiston would never have been propounded, and pneumatic chemistry would assuredly sooner have attained the rank of a science. But soon after the "Essays" were published, the discovery of the pressure of the air diverted the minds of the scientific from the study of the chemistry of the air.

The claims of Rey have never been sufficiently acknowledged. Let all honor be given to him; science ought to venerate such a man—a true philosopher, working for her, and loving her for herself alone. In the history of pneumatic chemistry, the name of Rey deserves to stand side by side with those of Mayow, Hales, Priestly, Scheele, and Lavoisier.

Well did Rey write as the concluding words of his treatise:

"Le travail esté mien, le profit en soit au lecteur, et à Dieu seul la gloire."

To be Continued.

On the Employment of Paraffin for Waterproofing. By John Stenhouse, LL.D., F.R.S., etc.

From the Practical Mechanics' Journal, April, 1865.

The materials which in modern times were first employed for waterproofing were beeswax and the various kinds of drying oil, especially linseed oil, which were rendered more siccative by boiling or some other of the processes usually employed for that purpose.

About forty years ago caoutchouc was first successfully used, for rendering fabrics and other materials waterproof, by the late Mr. Chas. Macintosh; and after an interval of about twenty years, gutta percha was first imported into this country, and immediately applied for similar purposes.

In 1832 paraffin was discovered by Reichenbach in the course of his admirable researches on wood and coal tars. He, however, only succeeded in obtaining it in very small quantity, so that for a long time it was only known as a chemical curiosity. It is to Mr. James Young that we are indebted for the production of this material on an industria scale, by his process which he patented nearly fifteen years ago.

About three years since a patent was taken out by Dr. Stenhouse for employing paraffin as a means of rendering leather waterproof, as well as the various textile and felted fabrics; and in August last an additional patent was granted Dr. Stenhouse for an extension of and improvement on the previous one, which consisted chiefly in combining the paraffin with various proportions of drying oil, it having been found that paraffin alone, especially when applied to fabrics, became to a considerable extent detached from the fibre of the cloth after a short time, owing to its great tendency to crystalize. The presence, however, of even a small quantity of drying oil causes the paraffin to adhere much more firmly to the texture of the cloth, from the oil gradually becoming converted into a tenacious resin by absorption of oxygen.

In the application of paraffin for waterproofing purposes, it is first melted together with the requisite quantity of drying oil and cast into blocks. This composition can then be applied to fabrics by rubbing them over with a block of it, either cold or gently warmed, or the mixture may be melted and laid on with a brush, the complete impregnation being effected by subsequently passing it between hot rollers. When this paraffin mixture has been applied to cloth, such as that employed for blinds or tents, it renders it very repellent to water, although still pervious to air.

Cloth paraffined in this manner forms an excellent basis for such articles as capes, tarpaulins, &c., which require to be rendered quite impervious by subsequently coating them with drying oil, the paraffin in a great measure preventing the well known injurious influence of drying oil on the fibre of the cloth. The paraffin mixture can also be very advantageously applied to the various kinds of leather. One of the most convenient ways of effecting this is to coat the skins or manufactured articles, such as boots, shoes, harness, pump-buckets, &c., with the melted composition, and then to gently heat the articles until it is entirely absorbed. When leather is impregnated with the mixture, it is not only rendered perfectly waterproof, but also stronger and more durable. The beneficial effects of this process are peculiarly observable in the case of boots and shoes, which it renders very firm without destroying their elasticity. It therefore not only makes them exceedingly durable, but possesses an advantage over ordinary dubbing in not interfering with the polish of these articles, which, on the whole, it rather improves.

The superiority of paraffin over most other materials for some kinds of waterproofing consists in its comparative cheapness, in being easily applied, and in not materially altering the color of fabrics, which, in the case of light shades and white cloth, is of very considerable importance.

It will be evident from the statements which have just been made, that the employment of paraffin for waterproofing purposes is likely to become very extensive.

Gunpowder Extraordinary.

From the London Mechanics' Magazine, March, 1865.

Captain Schultze, of the Prussian artillery, has just patented, both in England and in most continental countries, a new kind of gunpowder, which possesses some very valuable advantages, and seems to us destined to play an important part in the world. As regards its absolute composition, and also its mode of manufacture, it bears more resemblance to gun-cotton than to ordinary gunpowder; but its form is that of gunpowder, and it has none of those specially dangerous properties which have hitherto prevented gun-cotton from coming at all extensively into practical use. Cotton fibre, it might be well to explain, consists of a substance which chemists call "cellulose," and which is a compound of six atoms of carbon, five atoms of oxygen, and ten atoms of hydrogen; while gunpowder is, chemically speaking, "tri-nitro-cellulose," or cellulose which has had three atoms of its hydrogen taken away and replaced by hyponitric acid. Further, all kinds of wood consist chiefly of cellulose; the cellulose of wood, however, unlike that of cotton fibre, which is quite pure, being always combined with more or less of coloring matter, resin, and various earthy and other substances. This being the case, it is obvious that if we could remove from wood all the substances other than cellulose which enter into its composition, and were to subject the pure cellulose which would then remain to the same chemical treatment that cotton fibre has to undergo in order to its conversion in gun-cotton, we should obtain a substance of absolutely the same composition as gun-cotton, and differing from gun-cotton only in form. This is just what Captain Schultze does, with the result, among others as important, that he gets his "tri-nitro-cellulose," not in delicate filaments, like those of gun-cotton,—a mass of which, of whatever size, on the application of a spark to any part of it, will flash into combustion almost instantaneously, exploding, indeed, with such exceeding rapidity that a charge of it ignited in the powder-chamber of a gun, against a ball pressed tightly home to it, would burst the gun instead of propelling the ball,—but in hard, compact grains of any desired dimensions, and at least as slow of combustion as the densest gunpowder of the same size of grain. While gun-cotton,—being, at least for gunnery purposes, only three times as powerful as its weight of gunpowder,—costs, weight for weight, six times as much as gunpowder costs, and can only be used safely by means of special methods, Captain Schultze's granular tri-nitro-cellulose, while being nearly four times as powerful as gunpowder, costs, weight for weight, considerably less than gunpowder, and can be used in precisely the same way as gunpowder, its substitution for gunpowder requiring no new method or precaution beyond that of using of the new powder only one-fourth as much as of the old. The new explosive agent has thus great advantages, alike over the old "villainous compound" of charcoal, sulpher, and saltpetre, which Martin Schwartz invented five hundred years ago, and which has influenced human affairs perhaps as much as the printing press or the mariner's compass, and over the singular substance the discovery of which by Schönbein, in 1846, if it has done nothing at all towards bringing about that entire disuse of gunpowder which its distinguished discoverer predicted that it must occasion within ten years, has at least enabled the art of photography to reach a pitch of perfection, which, but for gun-cotton, or rather the solution of it in ether, which is known as collodion, would have been impossible. To this it must be added that Captain Schultze's powder does not foul the guns in which it is used; that the products of its combustion are perfectly transparent gases, offensive neither to the eyes nor to the lungs, and lighter than the atmospheric air, so that they soon pass away; and that its manufacture is much safer than that either of gunpowder or of gun-cotton.

The first process in the manufacture of the new powder is to cut some wood—we are told that any kind will do, but that the harder it is the stronger the powder will be—into sheets or veneers, of a thickness equal to the diameter which it is desired that the grains of the powder to be produced shall have. For powder to be used for ordinary small arms, Captain Schultze recommends that the sheets be about one-sixteenth of an inch thick. These sheets, whatever their thickness, are cut up by a punching apparatus into little cylinders, of diameter slightly less than the thickness of the sheets from which they are cut. The cylinders thus obtained constitute, eventually, the grains of the new powder, which is thus granulated at the beginning, instead of, like the ordinary gunpowder, at the end of its process of manufacture. In order to remove from these cylinders, or grains, all their constituents other than cellulose, they are boiled for about eight hours, in a copper kettle, in a strong solution of carbonate of soda, the solution being changed as often as it becomes discolored; they are then kept in a stream of running water for twenty-four hours, and are next steeped for about two or three hours, being constantly stirred all the time, in a solution either of chloride of lime or of chlorine gas. They are then well washed, first in cold water and afterwards in hot; and are finally kept for a second time twenty-four hours in pure cold running water. They are then submitted for six hours to the action of a mixture of forty parts by weight of concentrated nitric acid with a hundred parts by weight of concentrated sulphuric acid, one part by weight of the grains being placed with seventeen parts by weight of the mixed acids in an iron vessel, which should either be placed in a powerful refrigerating mixture, or have cold water constantly circulating around it. At the end of six hours the grains are taken out, and carefully drained from all adhering acid. They are then kept in cool fresh running water for two or three days, then boiled in a weak solution of carbonate of soda, then exposed to running water again for twenty-four hours, and then dried as completely as possible. Captain Schultze states—somewhat to our surprise—that up to this point the grains are not explosive, and that this drying operation therefore involves no danger. When fully dried, the grains are ready for the last operation but one, which consists in steeping them for ten minutes in a solution of some salt or salts containing oxygen and nitrogen. Captain Schultze prefers nitrate of potash (saltpetre) or nitrate of barytes, or, what he finds is better still, a mixture of both. He recommends for every hundred parts by weight of the grains, two hundred and twenty parts of water, having dissolved in it twenty-seven and a half parts of nitrate of potash and seven and a half parts of nitrate of barytes. The temperature of the solution should be 112° Fahr. After having been stirred about in this solution for ten minutes, the grains have only to be taken out and drained, and then dried. The drying must be done, this time, in a chamber kept at a temperature of from 90° to 112° Fahr., and will occupy about eighteen hours.

We have spoken again of gun-cotton as being, for gunnery purposes, only three times as powerful as gunpowder. Intrinsically, it is six times as powerful as gunpowder, and in applications to mining and engineering purposes, and also as a charge for shells, it has practically six times the value of its weight of gunpowder. No method is known, however, by which the *whole* of the force generated by its combustion can be utilized for the propulsion of projectiles from guns. For gun-cotton to exert the utmost energy of which it is capable, it must be compressed as much as possible, and exploded in the most confined space into which it can be got; but if a charge of gun-cotton be rammed down in a gun, after the manner of an ordinary powder charge, its explosion, as already stated, will burst the gun before the ball has had time to begin to move. Not only, therefore, must gun-cotton intended for use in guns not be compressed at all, but it must be allowed more space in the gun than it is capable of filling, even without compression. "It is a discovery of General Lenk," said Mr. Scott Russell, in the paper on gun-cotton which he read before the Royal Institution some months ago, and which we reported at the time, "that to enable gun-cotton to perform its work in artillery practice, the one thing to be done is to *give it room*. Don't press it together; don't cram it into small bulk! Give it at least as much room as gunpowder in the gun, even though there be only one-third of the quantity (measured by weight). . . . . . . The ramming down which is essential to the effective action of gunpowder is fatal to that of gun-cotton. To get useful work out of a gun-cotton rifle, the shot must on no account be rammed down. Air left in a gunpowder barrel is often supposed to burst the gun; in a gun-cotton barrel it only mitigates the effect of the charge. The charge for a gun-cotton rifle must be enclosed in a hard, strong pasteboard cartridge, to keep the cotton from compression and give it room to do its work. . . . . For artillery, a hollow space must be preserved in the centre of the cartridge, by some means or other. The best means is to use a hollow thin wooden tube to form a core. This tube should be as long as to leave a sufficient space behind the shot for the gun-cotton. On this long core, gun-cotton yarn is wound round, like thread on a bobbin." These expedients certainly prevent the gun-cotton from bursting the guns, but they also prevent it from exerting upon the shot more than one-half of the energy set free by its combustion.

The discovery by Baron Lenk, who is a Major General in the Austrian service, of this safe method of using it in guns, and also of improvements in its manufacture, rendering it both less liable to spontaneous combustion and in every way safer, both to store and to handle, than when manufactured as formerly, have caused more attention to be given to gun-cotton in this country, both by military and by civil engineers, during the last twelve months, than ever before. Considerable quantities of it have been manufactured lately by Messrs. Thomas Prentice and Co., of Stowmarket; and among miners and civil engineers, for whose special purposes it possesses great advantages over gunpowder, it has been growing rapidly into favor. As an illustration of the value of the advantage which is constituted by its explosion producing no smoke, Mr. Scott Russel in the lecture just quoted from, stated, that if gun-cotton were to be used instead of gunpowder in the completion of the tunnel which is being bored through Mont Cenis, the final completion of that great enterprise would be hastened many months, owing to the workmen being able to return to their tasks almost the instant after an explosion of gun-cotton, whereas after an explosion of gunpowder, under such circumstances as in the Mont Cenis tunnel, the air in the immediate neighborhood is unbreathable for a considerable time. Captain Schultze's powder, however, as we have seen, shares with gun-cotton both this and all the other advantages of that substance, and possesses in addition several important advantages which are exclusively its own.

Improvements in Fire-arms.

Translated for the Journal of the Franklin Institute.

Mr. Seguier presented to the French Academy of Sciences a very interesting memorial upon improvements in fire-arms. The idea which underlies his proposed improvements is that of putting the ball in motion at first gradually and increasing the pressure upon it as it gains velocity, under such conditions that all the force of the explosion may be exhausted before the ball leaves the gun. For this purpose various expedients are suggested: the ignition of the charge first at its front part immediately in contact with the ball; the interposition of an air-space between the charge and the ball, so that the air may act by its elasticity, (neither of these proposals are new;) the forming the charge of two kinds of powder, a slow burning to be first ignited, and a more rapid to act on the ball after its inertia had been overcome. A modification of this latter consists in using gun-cotton in place of the rapidly burning powder. The cartridges made upon this principle by Mr. Chaudeur, are claimed as giving the following advantages:

1st. An economy, by avoiding the loss of powder thrown out of the piece unburnt. This is gained by igniting the front part of the charge.

2d. A reduction of the recoil, by the insertion of an air-chamber between the breech-piece and the charge.

3d. An increase of the range, by the combination of slow and quick burning powders in the same cartridge.—*Cosmos.*

For the Journal of the Franklin Institute.

Coal Trade in Europe.

The extraction of coal in France during 1863, is estimated at 10,000,000 tons; as the importation of foreign coal was 5,344,260 tons, the consumption amounts to 15,344,260 tons, or about 400 kil. (882 lbs.) per head. Belgium produced 10,000,000 tons, but exports 3,500,000 tons. The 6,500,000 tons which it consumes represent 1280 kil. (2822 lbs.) per head, or three times as much as in France. England produced 86,000,000 tons of coal, of which 7,934,000 were exported. The internal consumption is then 78,000,000 tons, which represents 2900 kil. (6394 lbs.) per head, or about seven times as much as in France. One-third of the coal used in France is imported from England Belgium and Prussia.—*Cosmos.*

Preparation of Aluminium.

From the London Artizan, Mar., 1865.

Mr. Corbelli has found a simpler and more economical process for procuring aluminium than that heretofore used. The metal is prepared from clay, first carefully purified from foreign matter, then dried and treated by an acid to remove iron. About six times its weight of sulphuric acid will answer this purpose. The clay is then allowed to settle, dried again, and mixed with about twice its weight of prussiate of potassa, the quantity of which is to be increased or diminished according to the contents of silica in the clay. To this mixture one and a half times the weight of the clay is added of common salt, the mixture placed in a crucible, and heated to a white heat. After cooling, the aluminium will be found at the bottom of the crucible.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, April 20th, 1865.

The members were called to order by the President, Wm. Sellers, in the chair, the number present being 32, as per roll.

The minutes of the last meeting were then read and approved. The minutes of the Board of Directors were reported, as also those of the Standing Committees. The Special Committee on Weights, Measures, and Coinage, reported progress; as also the Committee on Steam Expansion, and the Committee to draft a petition to Councils, regarding the appointment of an inspector of steam boilers, presented the petition, engrossed and ready for transmission.

Donations to the Library were received by the Board of Managers, viz: From the Royal Institution and the Society of Arts, London; the Royal Irish Academy, Dublin, Ireland; Thos. Oldham, Esq., Superintendent of the Geological Survey of India, Calcutta, India; the Smithsonian Institution and Frederick Emmerick, Esq., Washington, D. C.; the Managers of the Lunatic Asylum, Utica, N. Y.; the American Philosophical Society, H. P. M. Birkinbine, Esq., Prof. John F. Frazer, the Directors of the Girard College, and B. F. Palmer, Esq., Philadelphia.

New business being then in order, Prof. F. Rogers, as chairman of the Committee on Meetings, introduced to the members of the Institute, Mr. Albert Leeds, who then read a paper as follows, on

The Geography and Geology of Petroleum.

The northenmost point on the American Continent at which petroleum has been largely found is in Canada West, at Enniskillen, near Lake St. Clair. The accounts of the quantities which have issued from single wells in this locality are too well authenticated to be doubted. In the year 1862, when Pennsylvania produced so much oil that its commercial value became too low to make it profitable to pump wells distant from a market, these Canada wells were allowed to overflow with oil acres of ground. They became choked up by neglect, and it is but recently that they have been reopened and properly worked. Lying nearly on the same parallel are, to the eastward, Lockport, in Niagara county, New York, and Hamilton, in Canada, on the shores of Lake Ontario; to the westward, St. Clair county, Michigan. In all these localities oil has been found.

They constitute, in fact, a boundary line 200 miles in length, which limits the oil regions upon the north. Now, carry this line southward for 350 miles. It will stop near the source of the Kanawha River, upon the slopes of the Alleghany Mountains, in West Virginia. This tract, 200 miles broad, 350 miles long, and embracing 70,000 square miles, is at present the only region east of the Rocky Mountains, where petroleum has been found in workable quantity. Now, if a diagonal be drawn from the northeast to the southwest corner of this tract, it will be seen

1st. That the Alleghany Mountains and the Blue Ridge Mountains are parallel to this diagonal.

2d. That the general course of the Ohio and Alleghany Rivers is likewise parallel to it.

3d. That all the rivers, creeks, brooks, and ravines where petroleum has been found, either in the valley-basins of those great rivers, or in the water-sheds which feed them, flow either parallel or at right angles to this same diagonal.

In concluding this short sketch of the geography of the oil regions, may it not be asked whether the great geographical fact stated above, has not some intimate connexion with the geology of petroleum and the action of oil wells?

Everywhere throughout the world geologists have found that certain rocks which are similar in chemical nature, in physical characters, and in organic remains, are always found in the same relative position to each other. Any series of rocks thus allied, is held to be the result of the same physical forces, and marks a distinct era in the building up of the crust of the globe, called a geological epoch. Such a group of rocks is called a formation. Deepest in the earth, and first in order in point of time, was built up a great group of rocks, all characterized by the absence of any trace of animal life. These are of unknown thickness. They underlie all other rocks, and man would have never known of their existence except for those mighty convulsions of nature which have rent asunder the earth's surface, and sent up through fissures or protruded from the craters of volcanoes the molten matter of these first foundation masses. Upon them rests a long series of sandstones and limestones of very varying thickness, known as the lower and upper Silurian systems. Another step towards the earth's surface brings us to the Devonian system, wherein we first find petroleum in the United States, and this, together with another great formation, called the carboniferous, include all the rocks from which has so far been obtained in the oil regions above referred to.

But any description of the oil-yielding rocks will be unintelligible, if it be for a moment supposed that the geological formations lie one upon another like the leaves of a closed book. Geology teaches that some mighty force, in ages long past, has operated from below in such a way as to bring up the edges of the lower layers of rock to the earth's surface. They would, therefore, appear to us like the edges of the leaves of a book, when the book was wide opened. And thus it happens that formations but two or three miles in thickness, may be stretched over hundreds of miles of the earth's surface, and that by beginning at some definite point and walking in the proper direction, we can in great detail the rocks which we wish to consider.

Let us take our geological sketch from the same point at which we took a bird's-eye view of the geography of the oil regions. Standing at Enniskillen, let us look far away to the southwest along the line of that diagonal to which I have already called your particular attention. At Enniskillen petroleum is found in the corniferous limestone which occupies the lowest point of the Devonian system. This corniferous limestone is composed in great measure of fragments of corals and sea-shells. The cavities of these corals and sea-shells are often filled with liquid bitumen, and the inhabitants of those places where this corniferous limestone exists, find the bitumen issuing in the form of tar from the kilns in which they reduce this rock to lime. According to an analysis made by Hunt, the chemist of the Canadian Geological Survey, specimens of this corniferous limestone yielded from 7·4 to 12·8 per cent. of bitumen, fusible, and readily soluble in benzole. Its thickness in Enniskillen is about 100 feet. Lying directly above the limestone is the Marcellus shale. Throughout this and the formation next to be described, there are many septaria or modular concretions highly charged with bitumen. This Marcellus shale is about 50 feet thick in that part of Canada lying between Lake Ontario and Lake Huron. And in the cavities and fissures of these two rocks, which in Canada are not above 150 feet in thickness, was stored up thousands of years ago those millions of gallons of petroleum hitherto found in Canada. But Lake Erie intervenes, and we must therefore cross over to Western New York if we wish to inspect the rocks in the same order as that in which we commenced.

The rocks which here yield petroleum are found in what New York geologists call the Hamilton group, which lie above the Marcellus shale and corniferous limestone in the geological scale. The oil springs in the vicinity of Lockport and along the banks of Chautauque and other lakes in western New York, are mainly in this group of rocks. In fact, it was from Seneca Lake that the oil was brought, which the Indians traded away to the early white settlers of Pennsylvania and New York, and it was by the tribe which inhabited that lake—the Senecas—that the use of petroleum as a healing ointment was made known. Petroleum was first sold in this country by druggists, under the name of "Seneca Oil." Western New York is now being diligently prospected and already Chautauque Lake is glowingly depicted in the prospectus of a new oil company. In the black shales which exist in the southwestern part of New York, and which are known as the Genessee slates, no oil has yet been found. But where the same rocks reappear far away to the southwest, at Mecca, Ohio, they are found to yield a large supply of lubricating oil. We will put down the thickness of these rocks at 300 feet.

Proceeding further in the same direction, we find the shales and limestones of the Portage group, yielding oil from those wells on Oil Creek, which have been sunk to the greatest depth. These rocks at Oil Creek are 1700 feet thick. Above this, again, we find a long series of alternate slates and sandstones, the latter being sometimes replaced by limestone. If you take a drawing of the rocks in Venango county, wherever the quarryman has blasted away the hill-side, whether you look 400 feet above, or at the rocks just before your feet; whether you make the drawing of rocks along the Big Sandy, or up Sugar Creek, at Walnut Bend, along Oil Creek, or up Cherry Run, everywhere you will get a picture of thin argillaceous shales alternating with sandstones. If an accurate record of any well sunk in Venango county be consulted, it will reveal the same geological structure. As, for example, the following, which I copy from my note-book of a well upon the Alcorn farm, situated upon the Alleghany River, about three miles above Oil City:

Seventy-five feet of a very soft rock, of the nature of gravel; very soft.

Seventy-five feet of a rock, called by the drillers "soapstone." It is, in reality, an argillaceous shale. It has a somewhat gray color, and is harder than the preceding rock.

Ten feet of sandstone, everywhere known as "the first sand rock."

Seventy-five feet, another series of shales distinctly argillaceous.

Twenty feet, "second sand rock."

Two hundred feet, argillaceous slates. Layers of rock, alternately soft and hard.

Fifteen feet, "third sand rock."

Eighty feet, argillaceous slates, which the man who was boring described as "shelly," meaning that they were in thin layers of alternately hard and soft rocks.

If we sum up this record we have 550 feet of this formation in a vertical line. The man who was drilling this well said at the depth of 730 feet, which was the greatest depth he had attained, he had met the same kind of rocks. These rocks belong to the Chemung group, which lies immediately over the Portage, in the geological scale. We may, accordingly, safely estimate the thickness of the Chemung group in Venango county at 450 feet above the surface, plus 750 below, or at 1200 feet. In this group of rocks, nearly all the oil from Oil Creek, Cherry Run, Patchen's Run, Two-mile Run, Horse Creek, etc., has been found. The Catskill formation does not occur in the oil regions of Pennsylvania.

We have now reached the top of the Devonian system, and find, on adding up the above figures, that the total depth to which it has been developed in the oil regions is 4000 feet. Concerning all these 4000 feet of rocks, there is nothing which becomes more strongly impressed upon an observer of the geological features of northwestern Pennsylvania than the belief that they are sedimentary. That they are, in other words, nothing but the broken and pulverized fragments of other rocks which have been deposited from water; that northwestern Pennsylvania was the basin of an ancient sea, which was filled up by the debris of continents.

Ascending in the geological scale, we now come to the carboniferous system. None of the wells which have been sunk along Oil and French Creeks have ever passed through coal. The lowest member of the coal series caps the highest hills near the mouth of Oil Creek, and is, therefore, some five hundred feet above the top of any well which has been sunk in that region. The bituminous coal which exists here is of the poorest quality, and occurs in seams of only a foot or eighteen inches in thickness. But this coal has been selling there at sixty cents a bushel, and the cost of feeding the engine has been one of the principal items of expense in sinking a well. To the south, however, of Oil City, in Cranberry township, and along the Alleghany River, the coal veins become thicker. One stretching along the top of a hill, about seven miles below Franklin, is five feet in thickness. It is now being worked, and is expected to supply Franklin, Oil City, and the points above with superior coal. But Franklin is about five hundred feet above Pittsburgh, and the general dip of the rocks in a southerly direction is such that in the neighborhood of the latter town the carboniferous rocks come down to the surface.

In the territory around Pittsburgh, along the Kiskiminetas River, at Slippery Rock, throughout Butler county, at Smith's Ferry, etc., oil is found in the lower coal measures. In this locality they are 800 feet thick. If we trace the Kiskiminetas River nearest its source, oil is found in the lower coal measures, which are 1000 feet thick. Along the Muskingum, Kanawha, and other rivers and creeks about Marietta and Parkersburg, in Virginia and Ohio, such as the Horse-Neck, Bull and Goose Creeks, the upper coal measures contain the petroleum. They are here 700 feet thick. We have now the

Corniferous limestone,	50 feet.
Marcellus slate,	100 "
Hamilton group,	1000 "
Genessee slate,	300 "
Portage group,	1700 "
Chemung group,	1200 "
Lower coal measures,	800 "
Middle coal measures,	1000 "
Upper coal measures,	700 "
Total depth of oil yielding rocks,	6850 "

In view of these figures let us see what answer should be given to those who are fearful that petroleum is giving out; that nature has manufactured after a stingy fashion the most beautiful means of illumination which she has yet yielded to man; that the refining of petroleum will soon give place to the distillation of bituminous coal; that derricks and tanks will soon cease to villify the landscape of the beautiful Ohio basin; and that soon, with a terrible crash, oil companies will disappear, and leave nothing but paper behind.

Different wells scattered up and down over 70,000 square miles of land, are now producing oil in profitable quantities. In a large portion of this territory, geology and experience tells us that petroleum exists throughout rocks varying from 50 to 7000 feet in thickness. When petroleum has been exhausted by shallow wells, it may be found in deeper ones, as the famous wells along Oil Creek show us. Here wells were put down at first from two to three hundred feet, and a heavy lubricating oil was obtained, by pumping, in small quantities. Afterwards, in localities which had been abandoned as unprofitable, wells were sunk to five or six hundred feet, and flowed one thousand, two thousand, and even in some cases over three thousand barrels daily. Of 340 wells sunk previous to this date between Humboldt Refinery and Rouseville, all that have reached the proper depth have produced oil, and the remainder, 112 in number, will probably experience equal good fortune. These facts alone would justify the statement that henceforth petroleum deserves to be ranked with coal and iron as a solid mining interest.

Such an opinion, moreover, deserves additional weight from a study of the various tracts in Europe, Asia, and South America, where petroleum is collected; and since no statement of this kind has heretofore been published, it will be interesting and valuable to present in this place a world-wide view of petroleum wells. In so doing we must widen to a corresponding degree our ideas of the nature of petroleum. We must recollect that this mineral substance was known many years before the first oil well was sunk near Titusville, and that, under the general name of petrolum, many rock-oils should be included, differing greatly in their nature from those mobile fluids, which a Philadelphian who is familiar with the products of Oil Creek alone, is wont to regard as petroleum. We should remember that easily fusible, pitchy, bitumens are made up of two ingredients, one of which is a solid body like asphaltum, and the other an oily liquid resembling petroleum, and that wherever such bitumens are found, they are to be regarded as indications of the profitable presence of petroleum. Having made these preliminary statements, we are enabled to speak in a more general manner of foreign oil-bearing rocks, and are not compelled, as we would otherwise be, to regard the few places where petroleum is stated to exist by travelers, in precise terms to exist, as the only ones where it is really to be found.

Petroleum found in South America.—In South America bitumen has been discovered in large quantities on the northern shores of New Granada, Peru, and Venezuela, on the banks of the river Magdalena, at Payta or Payti in Columbia, at Coxitambo, near Cuenca, in Peru, and in many other places. Few of these bitumens have been analyzed, and we possess, at present, but few facilities for comparing them with European specimens. That of Coxitambo has been investigated, and has been found to be a pure hydrocarbon, consisting of 88·7 per cent. of carbon and 9·7 per cent. of hydrogen. In the Travels and Researches of Alexander Von Humboldt, an account is given of a stream of naphtha at the Punta d'Araya, at Cape Cirial, Venezuela. He says that it issues from mica slate, and remarks, as a singular fact, that petroleum should in this spot issue from a metamorphic rock, while at all others it exudes from secondary rocks. And Boussingualt, who has shown in his work on bitumen, that all the vast collections of mineral pitch which exist in the northern parts of South America, must have a geological position corresponding with bituminous schists found in France, quotes this remark of Humboldt, as the only one which goes to contradict his view of the geological position of the American mineral-pitch.

In McCulloch's *Geographical Gazetteer*, reference is made to a great mountain of asphaltum upon the northeastern shores of the great lake of Maracaybo. It sends up, in warm weather, great streams of phosphoric fire, which guide the Spaniards and Indians in ther transits over the lake. They have consequently given to this strange lamp of nature the name of the Lantern of Maracaybo. Around the border of the lake, a circumference of about two hundred and fifty miles, petroleum springs and bitumen abound.

West Indies.—Throughout many of the Islands of the West Indies, and to the north of Venezuela, petroleum springs are found, accompanied generally by deposits of bitumen and vast accumulations of asphaltum. These Islands have been upheaved from the sea, during a recent geological epoch, by violent volcanic action. This may account for the fact that petroleum does not, in the West Indian localities, issue from sedimentary rocks as it does in Pennsylvania, but from igneous rocks, or those which have been forced up to the surface of the earth by volcanic agencies. In very many places in Cuba, petroleum flows from cracks in serpentine rocks. Such petroleum springs have been found for two hundred years at Guanabacoa near Havana. And the narratives of the buccaneers tell us that they used to frequent the Bay of Havana, and collect sufficient bitumen lying exposed on the shore at low water, to pay the bottoms of their vessels. In the eastern part of Cuba, springs are found between Holquin and Mayari, and in the other direction in the neighborhood of Santiago de Cuba. Of the bituminous coal, or, as it is called by the natives, *chapapote*, found in Cuba, more than one-half is composed of volatile fatty matters. An analysis made by Mr. T. G. Clemson, of chapapote from the Casualidad mine, which is situated about 18 miles from Havana, gives only 34·97 per cent. of coke and the astonishing amount of 63 per cent. of volatile ingredients. It is, of course, an admirable material for the manufacture of gas.

In the great pitch lake of Trinidad there is a great number of holes and fissures, which have apparently been produced by a rending asunder of the hardened asphaltum by volcanic forces, and a subsequent injection of liquid bitumen. And, in fact, this strange operation of nature's hidden forces may sometimes be seen actually going on in the sea, to the southward of Cape de la Brea. Hidden beneath the waves there seems to be a submarine volcano, which sends up occasionally quantities of petroleum to the surface of the water, attended with a mighty boiling of the deep. And in the same manner, the seas in the vicinity of the Cape de Verde Islands are oftentimes covered with petroleum projected from submarine volcanoes. Many years ago an account was published by Dr. Skey in the English Geological Transactions of a "Petroleum or Burning Spring," found at St. Andrew's parish in the Island of Barbadoes. He states that it issues from calcareous rocks, and it would appear from his calling it *green naphtha*, and from the fact that it is largely employed by the natives as a substitute for fish-oil in lamps, that the petroleum of Barbadoes is nearly analogous to what we are here familiar with under this name. Mr. Herapath analyzed the coal found in Barbadoes, and found that it was equally rich with that mined in Cuba, consisting of 62 per cent. of fatty matters and 37 of coke.

Europe.—In the next place, let us examine the bituminous deposits of Europe. In England, little has been found compared with the extensive developments which have been made in France. Bitumen has been encountered at the Hurlet mines near Paisley, where it encloses crystals of calcareous spar, and at the Odin mines in Derbyshire. It strongly impregnates the peat cut near Ormskirk, Lancashire, and penetrates the limestones of East Lothian in Scotland.

About the year 1840, a mania, M. Dumas tells us, prevailed in France, for putting bitumen to countless industrial appliances. All the provinces of France were explored for asphaltums, bituminous mastics, mineral oils, bituminous schists, sands, sand and limestones, and some thirty different varieties of asphaltum were exhibited in 1843, by Parisian companies upon the bourse. In the year 1845, in the departments of Ain, Landes, Puy de Dome, Bas Rhine, Haut Rhine, Saône et Loire, there were 16 mines, employing 489 workmen, and yielding an annual revenue of one hundred and twenty-nine thousand dollars. This bore about the same proportion to the amount of money invested, as the yield from the petroleum wells of northwestern Pennsylvania and Virginia bears to the capital stock of the companies working them. But asphaltum would not do all that the ignorant newspaper writers of that day said it would, and soon fell in disfavor; companies crashed and thousands lost heavily. At present, bitumen, with a few exceptions, is restricted in its use to making roads, cisterns, and roofs watertight. The coal basin of Autun, in the department of Saône et Loire, contains largely worked beds of bituminous schists, producing on distillation an oil which is employed for gas-lighting. The bitumen of Seyssel is found in calcareous oolite, from which it is extracted by melting the broken rock in large cauldrons. In warm weather it has a thick pasty consistence and is tenacious, but in cold weather it is solid. It these respects it resembles the bitumens of Magdalena, Payta, and Trinity Island. The bitumen of Bechelbronn is viscous and of a brown color. It is put to many uses, and especially as a substitute for grease, in lubricating the axles of carriage wheels and the journals of machines. From these and similar applications, it has obtained the name of mineral oil, Stein oil, Strasbourg grease, etc. Like the bitumen of Coxitambo it is a pure hydrocarbon, containing 88 per cent. of carbon and 12 of hydrogen.

The bituminous rocks found in France are far surpassed by those of Dalmatia, on the northeastern shore of the Adriatic. The bituminous limestones found here seem to be so charged with liquifiable bitumen that they can be cut as easily as soap, and are formed into bituminous bricks for the sides of houses. When the walls have reached the required height they are set on fire, and burn until all the bitumen is consumed, leaving a white stone. The roof is then put on and the building completed.

In Italy petroleum is found in many places. That of Amiano in the Duchy of Parma supplies the city of Genoa with light. In the Duchy of Modena, petroleum springs are found at Saint Zibio, and in Sicily in the Val di Noto.

At Naples they appear to be connected with volcanic action, and to arise from the bottom of the sea near the southern base of Mount Vesuvius.

Passing over to the Ionian Islands we find large petroleum springs, of which the following account is condensed from the Colonial Statistics of the British Empire, published by Mr. R. M. Martin: The bitumen of Zante is contained in a valley or marshy plain, which is in the form of a segment of a circle, surrounded on three sides by abrupt and rugged ridges of hills. In the marsh within the circle are several wells or pits. The bitumen floats on the surface of the water in these wells. A dark substance continually forces its way from the bottom and boils up in large globules, which, enlarging till they ascend near the surface, then burst, and liberate a quantity of inflammable gas. Sometimes the globules are transparent and of singular brilliancy, rising to the top and bursting, while a coat of dark bituminous matter, in which they are invested, is thrown off. This dark substance is the *rock-pitch*, which, being specifically heavier than water, remains below, covering the sides and part of the bottom of the spring. The brilliant globules disengaged from it are pure *naphtha* or *rock-oil*, which forms a light oleaginous stratum above, reflecting various beautiful colors. The intervening water is sweet and fit for use. The pitch is collected with large spoons into a pit adjoining the well, and thence thrown into barrels. It is exuded in the greatest quantities in the summer months. About a hundred barrels are annually used for paying the bottoms of ships, and for similar purposes.

Passing by the petroleum springs of Neuchatel, in Switzerland, and at Tagernsee, Bavaria, let us next consider the bitumens of

Asia.—The petroleum wells of southern Asia are of peculiar interest. They were dug thousands of years ago, and when Babylon was in its glory, its skilful artizans made far more extensive use of this facile material than has been found for it at the present day. In a paper communicated by the famous Asiatic explorer, Major Rawlinson, to the Royal Geographical Society of London, he calls attention to the bitumen collected in Kordistan, formerly the great satrapoy of Susiana. He states that even at the present day, it is drawn from pits, dug in precisely the same manner as described by Herodotus, nearly three thousand years ago. What a treat to the indefatigable illuminator of Herodotus, this striking confirmation and illustration of the text of his favorite author, must have been.

The natives all along the Euphrates and Tigris, use the petroleum found along the banks of these rivers to pay the bottoms of their vessels, and to burn in lamps instead of oil. And throughout Persia, in the provinces of Farsistan and Kerman, which border upon the eastern shores of the Persian Gulf, in Afghanistan, in the district of Cahut, petroleum springs are found. To the northward, in the Isles of Naphtha, which are situated upon the eastern shores of the Caspian Sea, a vast bituminous formation has its origin. It stretches away to the westward for over a hundred miles, and terminates in the hills of the Crimea. It reappears on the western shores of the Caspian, in the peninsula of Abskharon, which forms the eastern end of the Caucasian chain, where it is fully developed as a great deposit of brown coal in a ridge of argillaceous shale. In the neighborhood are the renowned wells of the fire-worshipping Badkuans, who use petroleum for both light and fuel. These wells are inexhaustible and refill themselves as fast as emptied. No traveler has given any account of the development, which we would be prone to expect, of petroleum through the Caucasus and Georgia. But in the peniusulas of Kerch and Taman, at the entrance of the Crimean Sea, and near the western extremity of the Circassian range, it is found in considerable quantities. In the great mountain range which skirts the Red Sea, along all the western coast of Arabia, petroleum springs and deposits of bitumen abound in strata wholly composed of oceanic animal matter: countless fossil shells, and rocky crevices, and hollow stones are filled with it; and in the fervid heat of that climate it drops down from the precipitous sides of mountain gorges. And when we follow this great line of volcanic action to the northward, along the valley of Arabia, through the Dead Sea, and up the valley of the Jordan, even to Mt. Lebanon, we find scattered along its course deposits of bituminous matter.

Finally, we come to the territories of Assam, and the Birman Empire.

In the former, as narrated in the Asiatic researches by Lieut. Wilcox, there are, to the east of Brahmaputra, great jungles which are full of the odor of petroleum. Beds of white mud are of frequent occurrence through this region, resorted to greatly by cattle and wild beasts of all kinds, which eagerly devour this substance, probably from its saline properties. Petroleum floats on the edges of these mud springs, but neither it nor the the coal which is likewise found in the neighborhood is used by the natives.

Near the banks of the Irawadi River, between Prome and Ava, many wells of petroleum have been sunk to a depth exceeding two hundred feet. They are found along with beds of brown coal, and co-extensive with a tertiary clay formation. In the province of Pegu, around the town of Rainanghong are 180 naphtha wells; 340 others are situated four or five miles to the northeast. The gross amount of oil annually obtained from the 520 registered wells is about a hundred thousand tons, or four hundred and twenty thousand hogsheads, amounting in value to $817,392.

In answer to a question, Mr. Leeds remarked that he had *not* observed any evidences of coral formation in the oil regions of Pennsylvania.

Mr. Coleman Sellers remarked, that coral containing bitumen was found through Kentucky, and that boring for oil had been undertaken in that region, while even in southern Illinois oil was found on the surface of some salt wells, and has been known thus to exist, and even to have been collected, for many years.

Prof. F. Rogers remarked, that in cutting the tunnel of the Chicago Water Works, under Lake Michigan, many boulders, saturated with petroleum, had been encountered, while again specimens of coral-bearing rocks from western New York, saturated with petroleum or bitumen, had also come within his observation.

Mr. Fleury remarked, that the common association of petroleum with salt water seemed to indicate that the former had resulted from the decomposition of sea-weeds, subjected in former ages to pressure and "*wet heat.*" He then described a process for the conversion of benzine into burning oil, by the catalytic action of lubricating oil, at a high temperature, this being accomplished at the same time with the distillation of the crude oil, in an apparatus of peculiar construction, patented by Adolph Millochau, of New York.

SECRETARY'S REPORT.

Engineering Works.—It is now proposed to work the steep incline on the Mt. Cenis Railroad near the summit, by hydraulic engines, supplied with water from the lake on the top of the mountain, which will suffice for two engines, of 800 horse power each. Such machines, though rarely used in this country, have been largely employed in certain localities, as at Nesselgrabe and elsewhere, in upper Bavaria; and in the cutting of this very tunnel, hydraulic machines of peculiar action, analogous to that of the water ram, were used to compress air, which in turn operated the drilling apparatus.

The rapid progress of engineering works in the East, is worthy of note. The railroad from Alexandria to Suez, has now a rival in the canal through the Isthmus, which is open across, though not yet cut to its full depth. The railroad through Palestine is likewise completed, the city of Alexandria is lit by gas, and a telegraph runs through Morocco.

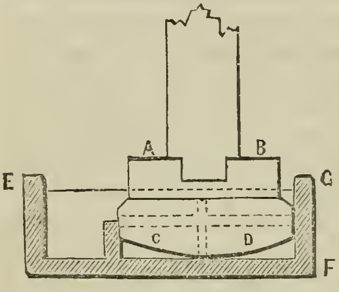
A railroad bridge has been constructed of Bessemer steel over the Sankey canal, England, the use of this material enabling the engineer to reduce by 40 per cent. the weight of the structure.

Mechanical Engineering.—Leading articles in some of the foreign journals and several patents in the same location, give expression to a difficulty in the direction of locomotive construction, which seems to press forcibly upon foreign engine builders and their customers, namely, the impossibility of combining great weight and tractive power with "flexibility" in turning curves, without overloading the driving wheels, and thus injuring the permanent way. These difficulties have long since presented themselves in this country, where our roads, carrying heavy material, such as coal and iron, over great distances, rendered some means of drawing at once long trains, by single engines, of the greatest financial importance. We have surmounted the obstacles and obtained the desired results. 1. By building "tank" or other very heavy engines. 2. By giving these an extended wheel-base of 8, 10, or 12 coupled driving wheels; and 3. Removing the flange from most of these drivers, so giving "flexibility" in turning curves.

We give, for the benefit of those interested in the experiment, the particulars of the apparatus lately constructed for the Franklin Institute, to repeat Perkins' experiment of cutting hardened steel with a soft iron disk rotating at a high velocity. A disk of steel, such as is used for circular saws, but annealed so as to be very soft, is mounted on a steel spindle, which carries also a three-inch cast iron pulley, and the whole is then carefully balanced until it will rest indifferently in any position, on two straight edges. This spindle, &c., is then mounted in *cast iron swiveled* bearings. A belt, 2 inches wide, on the pulley is driven from a 36-inch pulley on an ordinary shaft, which carries also a 10-inch pulley, to which motion is given by a 4-inch belt from a 48-inch pulley on the engine shaft. The engine was run 120 revolutions per minute, which would give, with every allowance for "slip," between 5000 and 6000 revolutions per minute to the disk. At this velocity the hardest files were cut like soft wood, with the production of a blaze of light and showers of sparks, without the least injury to the edge of the soft disk.

The constructors of this apparatus were kindly furnished by Mr. Joseph Saxon, of Washington, with a general description of the machine originally made by him for Jacob Perkins in London, and in the above mentioned apparatus this description was followed, except where the improvements of modern machinery, warranted a deviation. The most important of these deviations was in the use of *cast iron* *swivel bearings.* In these the mobility of parts necessitates an equal distribution of the pressure and friction, over the whole surface of contact, and thus renders possible the use of a material otherwise so unfit as cast iron. The friction is in fact by this means brought between the steel and oil, and in no respect between the solid surfaces, at any point.

It may be well in this connexion to give some description of a means for supporting heavy upright shafting with the least possible friction, founded on the principle above mentioned, and not only in theory but in practice most efficient. The end of the upright shaft is secured in a large disk of cast iron A B, so proportioned that its lower face shall not have to bear a weight of more than 100 ℔s. per square inch. This rests upon another heavy cast iron disk C D, with a plane surface above, but below slightly curved; which lastly is secured in the strong cast iron box or case E F, which is filled with oil to E G. A few radial grooves are made in the lower face of A B, and the centrifugal action generated by its motion, thus constantly pumps oil through an upright tube in the centre of C D and distributes it over the rubbing surfaces. The important feature in this arrangement, is that the great surface, makes it possible to keep oil always between the rubbing parts, so that no friction of solid surfaces can occur, while any tendency to unequal bearing of the surfaces, is at once corrected by the “ rocking of C D upon its rounded base.



We describe this arrangement with the more pleasure, because it involves a principle of wide and various application, limited by no patent and free to the use of all.

Metallurgy.—The improvements and extensions of modern machinery have created a demand for some material much stronger than cast iron, and yet not much more costly, so that it may be used freely in the construction of extensive works. We are therefore glad to see that decided steps are being taken for the manufacture in this country of Bessemer steel, according to the improved processes which have reduced that department of metallurgy, to a condition of reliable efficiency. Two companies are already engaged on this work in America. Winslow & Griswold, of Troy, New York, who own the Bessemer patent, and have already produced excellent specimens of this steel, which they expect soon to send into the market, and the Pneumatic Steel Co., of Detroit, Michigan, who own the patents of William Kelley, and of Mr. Mushet. This last patent, covers the modification in the process consisting in the addition of iron, manganese, and carbon (generally in the form of the German Spiegel Essen, or our Franklinite, and charcoal) to over-refined Bessemer iron prepared in the way first devised. (Specimens and photographs of this steel, of foreign and domestic manufacture, were exhibited to the members.)

We have also to notice a process for the production of steel directly from the ore, proposed by G. Hand Smith, of Philadelphia. Pure oxide of iron, such as the magnetic oxide, for example, is crushed, washed, and packed in layers alternating with charcoal in the ordinary cementing furnace; after heating, a porous mass is obtained, which may then be rolled into plates.

A process for increasing the strength of cast iron by the addition of an alloy of zinc, lead, and tin, in the proportion of about 7 per cent., has also been presented by A. L. Fleury. This process is patented, and the amalgam prepared by W. M. Arnold, of U. S. Composition Iron Company, New York.

Mr. Fleury also described a process of manufacturing steel analogous to that of Bessemer, in which the decarbonization of the cast iron was effected by introducing into it, while melted, pulverized oxide, whose oxygen served to combine with and remove, the excess of carbon.

Mr. Lamborn mentioned that there had just been imported by the Penna. RR. Co., some 30 tons of Bessemer steel rails, this being the first large quantity of that material introduced in this country.

Prof. F. Rogers.—In connexion with these remarks about the locomotives, it is rather a curious fact that the subject of stationary engines has been opened again in England. Mr. Burleigh, who most members know as the celebrated writer on the strength of materials, has been estimating the motive power required for the railroads which go over the metropolis and those which go under the metropolis, and has been advocating stationary engines. He shows the advantages of the stationary engines from the fact that a great deal of time is consumed in getting up speed, and letting it down again, and it is proposed that the stationary engine shall push the train by the proper arrangements for the distance of a hundred yards, and permit it to go the rest of the distance by the impetus which the train has acquired, this being sufficient to enable it to pass the last station at the rate of 13 miles an hour.

Those members who have not noticed this, will find in the *Civil Engineers' Journal* a long account, which is quite interesting.

Since most engineers are opposed to it, it is barely possible that the thing may be tried, the principal objection which has been made to it lately, is the fact that the whole traffic depends upon a single engine. If the engine breaks down, or any serious accident occurs, the whole traffic must be suspended until repairs are completed. Of course, the danger of any disturbance, causing a breaking of the line, or the rail, is considerable, and as it cannot be repaired very readily, this is one of the most serious objections made to this system on the point of economy. It seems otherwise plausible. I mention it now as being curious, because in old times these stationary engines were largely used; we, however, use locomotives on heavy grades now, and the plan alluded to seems to be a retrograde movement.

After this, the meeting was, on motion, adjourned.

Henry Morton, *Secretary.*

A Comparison of some of the Meteorological Phenomena of April, 1865, *with those of* April, 1864, *and of the same month for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. Kirkpatrick, A. M.

	April, 1865.	April, 1864.	April, for 14 years.
Thermometer—Highest—degree, . .	79·00°	75·00°	88·00°
“ date, . . .	27th.	24th.	24th, 1861.
Warmest day—mean,	68·83	68·17	74·30
“ “ date,	27th.	24th.	29th, 1856.
Lowest—degree, . .	40·00	32·00	20·00
“ date, . . .	9th.	5th.	7th, 1857.
Coldest day—mean, .	45·50	37·17	27·70
“ “ date, .	9th.	5th.	2d, 1857.
Mean daily oscillation,	14·33	15·40	16·46
“ “ range, .	5·99	5·27	6·22
Means at 7 A. M., . .	51·25	44·90	45·86
“ 2 P. M., . .	62·03	55·58	57·47
“ 9 P. M., . .	54·48	48·45	49·59
“ for the month,	55·92	49·64	50·97
Barometer—Highest—inches, . . .	30·265 in.	30·048 in.	30·518 in.
“ date, ...	9th.	22d.	3d, 1854.
Greatest mean daily press.,	30·208	30·016	30·458
“ date, ...	9th.	22d.	3d, 1854.
Lowest—inches, . . .	29·404	29·310	28·884
“ date, ...	1st.	2d.	21st, 1852.
Least mean daily press., .	29·497	29·377	28·959
“ date, . . .	1st.	2d.	21st, 1852.
Mean daily range, . . .	0·172	0·122	0·169
Means at 7 A. M., . . .	29·897	29·730	29·820
“ 2 P. M., . . .	29·844	29·699	29·778
“ 9 P. M., . . .	29·889	29·755	29·810
“ for the month, .	29·877	29·728	29·803
Force of Vapor—Greatest—inches, .	0·689 in.	0·495 in.	0·689 in.
“ date, . .	29th.	25th.	29th, 1865.
Least—inches, . .	·120	·096	·066
“ date, . . .	24th.	7th.	13th, 1852.
Means at 7 A. M., .	·264	·219	·232
“ 2 P. M., .	·303	·232	·247
“ 9 P. M., .	·280	·236	·250
“ for the month,	·282	·229	·243
Relative Humidity—Greatest—per ct.,	93 per ct.	92 per ct.	100 per ct.
“ date, .	12th.	10th.	often.
Least—per ct., .	23·0	18·0	13·0
“ date, . .	24th.	7th.	13th, 1852.
Means at 7 A. M.,	67·0	71·0	71·2
“ 2 P. M.,	52·6	52·2	51·4
“ 9 P. M.,	64·4	67·8	67·4
“ for the month,	61·4	63·7	63·3
Clouds—Number of clear days,* . .	9	4	8·5
“ cloudy days, . .	21	26	21·5
Means of sky cov'd at 7 A. M.,	61·3 per ct.	62·7 per ct.	62·7 per ct.
“ “ “ 2 P. M.,	64·0	73·3	66·4
“ “ “ 9 P. M.,	51·0	69·0	53·4
“ “ for the month,	58·8	68·3	60·8
Rain—Amount, ...	2·829 in.	4·478 in.	4·813 in.
No. of days on which rain fell, . . .	11·	14·	13·0
Prevailing Winds—Times in 1000,	S53° 8′ W ·179	N13°23′W·133	N 63° 3′W ·148

*Sky, one-third or less covered at the hours of observation.

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

JUNE, 1865.

CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

Limes, Cements, Mortars, and Concretes. Collected from the observations and experiments of Generals Gilmore and Totten, U. S. A., and MM. Vicat, Chatoney, Rivot, and Dupont. By CHAS. H. HASWELL, Civil and Marine Engineer, N. Y.

No. 1.

The calcination of marble or any pure limestone produces *lime*, (*quicklime.*)

Lime, from its great affinity for moisture and carbonic acid, requires to be preserved from these deteriorating agents by being packed in close vessels.

Limestones.—The pure limestones burn to a white lime and give the richest limes.

The finest calcareous minerals are the rhombohedral prisms of calcareous spar, the transparent double-reflecting Iceland spar, and white or statuary marble.

In order that lime when brought to the condition of a paste for use as a binding medium shall afterwards harden to solidity, it is necessary that other substances exist in a state of intermixture with it; and these substances are found to be silica, alumina, magnesia, iron, manganese, &c.

The striking and characteristic property of hardening under water, or when excluded from the air, conferred upon a paste of lime by these foreign substances, when their aggregate amount exceeds one-tenth of the whole, furnishes the basis for a general arrangement of all natural or artificial products suitable for mortars, into five distinct classes, as follows:

1st. The common or fat limes.
2d. The poor or meagre limes.
3d. The hydraulic limes.
4th. The hydraulic cements.
5th. The natural puzzuolanas, including puzzuolana, properly so called, trass or terras, the arènes, ochreous earths, schists, grauwacké, and basaltic sands, and a variety of similar substances.

Rich limes are dissolved fully in water frequently renewed, and they remain a long time without hardening; they also increase greatly in volume, from 2 to 3·5 times their original bulks, and will not harden without the action of the air. They are rendered *hydraulic* by the admixture of *puzzuolana* or *trass.*

Rich, fat, or *common limes* usually contain less than 10 per cent. of impurities.

Hydraulic limestones are those which contain iron and clay, so as to enable them to produce cements which become solid when under water.

The pastes of fat limes shrink, in hardening, to such a degree that they cannot be used as mortar without a large dose of sand.

Poor limes have all the defects of rich limes, and increase but slighty in bulk.

The poorer limes are invariably the basis of the most rapidly setting and most durable cements and mortars, and they are also the only limes which have the property, when in combination with silica, &c., of indurating under water, and are, therefore, applicable for the admixture of hydraulic cements or mortars.

They generally contain silica (in the shape of sands), alumina, magnesia, oxide of iron, oxide of manganese, and, in most cases, traces of the alkalies in relative proportions which vary very considerably in different localities. Their aggregate amount is seldom less than ·10 or greater than ·25, although, in some varieties, it reaches as high as ·35, and even, though rarely, ·39 of the whole. In slaking, they proceed sluggishly as compared with the rich limes, and seldom produce a homogeneous and impalpable powder. They exhibit a more moderate elevation of temperature in slaking, and are accompanied by a much smaller increase of volume than rich limes. Like the latter, they dissolve in water frequently renewed, though more sparingly, owing to the presence of a larger amount of impurities, and, like them, they will not harden if placed in the state of paste under water or in wet soil, or if excluded from contact with the atmosphere, or carbonic acid gas. They should be employed for mortar only when it is impossible to procure common or hydraulic lime, or cement, in which case it is recommended, if practicable, to reduce them to powder by grinding.

Lime absorbs in slaking a mean of 2·5 times its volume and 2·25 times its weight of water.

Hydraulic limes are those which readily harden under water. The most valuable or "eminently hydraulic" *set* from the second to the fourth day after immersion; at the end of a month they become hard and insoluble, and at the end of six months they are capable of being worked like the hard natural limestones.

They absorb less water than the pure limes, and only increase in bulk from 1·75 to 2·5 times their original volume.

The inferior grades, or "moderately hydraulic," require a longer period, say from fifteen to twenty days immersion, and continue to harden for a period of six months.

The property of hardening under water or when excluded from air, conferred upon a paste of lime, is effected by the presence of foreign substances as silicum, alumina, iron, &c., when their aggregate presence amounts to one-tenth of the whole.

The resistance of hydraulic limes increase if the sand is mixed in the proportion of 50 to 180 *per centum* of the part in volume; from thence it decreases.

As a general rule these limes undergo, in slaking, an increase of volume inversely proportional to their hydraulicity and quickness.

Slaked lime is a hydrate of lime.

M. Vicat declares that lime is rendered hydraulic by the admixture of a proportion of from 33 to 40 *per centum* of clay and silica, and that a lime is obtained which does not slake, and which quickly sets under water.

Artificial hydraulic limes do not attain, even under favorable circumstances, the same degree of hardness and power of resistance to compression as the natural limes of the same class.

The close-grained and densest limestones furnish the best limes.

Hydraulic limes lose or depreciate in value by exposure to the air.

Arènes is a species of ochreous sand claimed to be of fossil origin. It is found in France. On account of the large proportion of clay it contains, sometimes as great as seven-tenths, it can be made into a paste with water without any addition of lime, and hence it is sometimes used in that state for walls constructed *en pisé*, as well as for mortar.

Mixed with rich lime, it gives excellent mortar, which attains great hardness under water and possesses great hydraulic energy.

Puzzuolana is of volcanic origin. It comprises trass or terras, the arènes, some of the ochreous earths, and the sand of certain grauwackés, pramuntes, granites, schists, and basalts; their principal elements are silica and alumina, the former preponderating. None contain more than ten per cent. of lime.

When finely pulverized, without previous calcination and combined with the paste of fat lime, in proportions suitable to supply its deficiency in that element, it possesses hydraulic energy to a valuable degree. It is used in combination with rich lime, and it may be made by slightly calcining clay and driving off the water of combination at a temperature of 1200°.

Trass or terras is a blue-black trap, is also of volcanic origin.

It is obtained from pits of extinct volcanoes, and has nearly all the distinguishing elements of puzzuolana, resembling it in composition and in the requirements of its manipulation, requiring to be pulverized and combined with rich lime, to render it fit for use and to develop any of its hydraulic properties.

For an analysis of them, see Busnell on limes, cements, mortars, &c.

Brick or Tile dust combined with rich lime possesses hydraulic energy.

General Gilmore* designates the varieties of hydraulic limes as follows: If, after being slaked, they harden under water in periods varying from fifteen to twenty days after immersion, *slightly hydraulic*; if from six to eight days, *hydraulic*; if from one to four days, *eminently hydraulic.*

The aggregate of silica, alumina, magnesia, oxide of iron, &c., contained in these limes seldom exceeds ·35 of the whole. The proportion in the first class varying from ·10 to ·20 of the whole, in the second class from ·17 to ·24, and in the latter class from ·20 to ·35.

Pulverized silica burned with rich lime produces hydraulic lime of excellent quality. In experiments by MM. Chatoney and Rivot, this lime hardened under water in from three to four days, and acquired in twenty-two months a hardness superior to Portland cement.

The weight of the powdered lime never exceeded four times, and never less than one-half that of the powdered silica.

Hydraulic limes in their composition, and in their value for application to the purposes of construction, and in their geological position, occupy an intermediate place between the *common or fat* limes and the hydraulic cements. They are found in the United States in numerous and extensive deposits.

Hydraulic limes are injured by air slaking, in a ratio varying directly with their hydraulicity, and they deteriorate by age.

For foundations in a damp soil or exposure, hydraulic limes must be exclusively employed.

Cements.

Hydraulic cements contain a larger proportion of silica, alumina, magnesia, &c., than any of the preceding varieties of lime; they do not slake after calcination, and they are superior to the very best of hydraulic limes, as some of them set under water at a moderate temperature (65°) in from three to four minutes; others require as many hours. They do not shrink in hardening and make an excellent mortar without any admixture of sand.

Roman Cement is made from a lime of a peculiar character found in England and France, derived from argillo-calcareous kidney-shaped stones, termed "Septaria," and when mixed thick it solidifies in a few minutes either in air or water; hence, for some purposes, it is of great utility and for others its use is impracticable.

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*See his Treatises on Limes, Hydraulic Cements, and Mortars, of Papers on Practical Engineering, Engineers' Department, U. S. A.

The manufactured article takes its name from the locality of the store, as "Boulogne" or "Sheppy."

Rosendale cement, from the township of Rosendale, N. Y., is derived from the water limestone of the Helderburg group, Ulster county, New York.

Portland cement is made in England and France from an argillo-calcareous deposit, which is burned and ground up for cement in its natural state, without the addition of lime. It requires less water than the Roman cement. It sets slowly, and can be remixed with additional water after an interval of twelve or even twenty-four hours from its first mixture.

The property of setting slow may be an obstacle to the use of some designations of this cement, as the Boulogne, when required for localities having to contend against immediate causes of destruction, as in sea constructions having to be executed under water and between tides. On the other hand, a quick setting cement is always difficult of use; it requires special workmen and an active supervision. A slow setting cement, however, like the natural Portland, possesses the advantage of being managed by ordinary workmen, and it can be remixed with additional water after twelve or even twenty-four hours.

Artificial cement is made by a combination of slaked lime with unburnt clay in suitable proportions, burning the mixture in a kiln or furnace and then grinding it, or by substituting for the lime a carbonate of a lime that can be pulverized without burning, or by using artificial puzzuolana, or by adding silica in a soluble form to a paste of common lime.

Artificial puzzuolana is made by subjecting clay to a slight calcination.—(*Pambour.*)

Salt water has a tendency to decompose cements of all kinds.

Mortars.

Lime or cement paste is the cementing substance in mortar, and its proportion should be determined by the rule, that *the volume of the cementing substance should be somewhat in excess of the volume of voids or spaces in the sand or coarse material to be united.* The excess being added to meet imperfect manipulation of the mass.

Hydraulic Mortar.—If re-pulverized and formed into a paste after having once *set*, immediately loses a great portion of its hydraulicity and descends to the level of the moderate hydraulic limes. A great destruction of the hydraulic principle therefore results from any disturbance of the molecular arrangement of the mortar, after crystalization has commenced. This is what occurs with the *intermediate* limes, which take initial *set* promptly and firmly, but which are subsequently thrown down by the slaking of the impure caustic lime which they contain.

All mortars are much improved by being worked or manipulated, and as rich limes gain somewhat by exposure to the air, it is advisable to work mortar in large quantities, and then render it fit for use by a second manipulation.

*Analyses of Hydraulic Limes, Cements, Trass, and Puzzuolana.**

No.	Specific Gravity.	Carbonic Acid.	Potash, Soda.	Silica, Alumina, Iron.	Lime.	Carbonate of Lime.	Magnesia and Carbonate.	Acids, Chlorides, Phosphates, &c.	WHERE FROM.
1	2·652		·62 ·88	25·20 6·16 2·02		58·84	10·38	·48	Utica, Illinois,
2	2·678		·40 12·10	19·66 3·14 3·86		40·54	17·98	·72	Sandusky, Ohio.
3	2·680		1·54 4·64	24·74 16·74 6·30		41·80	4·10	2·22	Cumberland, Md.
4	2·753			17·84 4·60 1·70		58·25	11·16	·74 3·26	Shepherdstown, Va.
5	2·844			18·52 2·18 1·86		43·30	26·04	1·96 4·24	High Falls, Ulster co., N.Y.
6	2·735			29·34 5·74 1·76		33·54	20·80	1·02 5·80	Do: do. do.
7	2·822			19·64 7·52 2·38		30·72	35·10	·64 4·10	Do. do. do.
8	2·761			18·46 4·22 2·32		37·50	35·62	·20 1·68	Do. do. do.
9	2·786			27·70 2·34 1·26		46·00	17·76	·26 4·02	Do. do. do.
10		31·00		18·00 5·25	30·20		·20		Sheppy, Eng., cement stone
11		29·00		17·75 6·00	35·00		·50		Nos. 1 and 2.
12		29·77		12·00 8·80	34·08		1·52		Southend, Eng. do.
13		31·00		24·00 1·31	30·50		1·04		Yorkshire, do. do.
14		22·75		9·375 17·75	29·25			7·50	Harwich, do. do.
15			7·0 1·0	57·0 5·0	2·6		1·0		Trass.
16			1·4 4·0	44·5 12·0	8·8		4·7		Puzzuolana.

Nos. 1 to 9 were analyzed by Prof. E. C. Boynton, Miss., and Nos. 10 to 16 by Berthier.

White lime will take a larger proportion of sand than brown lime.

The use of salt water in the composition of mortar injures the adhesion of it.

Mortar.—When a small quantity of water is mixed with slaked lime, a stiff paste is made, which, upon becoming dry or hard, has but very little tenacity, but, by being mixed with sand or like substances, it acquires the properties of a cement or mortar.

The proportion of *sand* that can be incorporated with mortar depends partly upon the degree of fineness of the sand itself, and partly upon the character of the lime. For the rich limes, the resistance is increased if the sand be in proportions varying from 50 to 240 *per centum* of the paste in volume; beyond this proportion, the resistance decreases.

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* From Practical Treatises on Limes, Cements, and Mortars. By Gen. Gilmore, U. S. A.

Stone mortar.—325 ℔s. cement, 120 ℔s. lime, and 14·67 cubic feet of sand.

Brick mortar.—325 ℔s. cement, 120 ℔s. lime, and 12 cubic feet of sand.

Brown mortar.—Lime one part, sand two, and a small quantity of hair.

Lime and sand, and cement and sand, lessen about one-third in volume when mixed together.

(To be continued.)

The Catchment Basins of Rivers.

From the Lond. Civ. Eng. and Arch. Journal, February, 1865.

When Bramah about thirty-five years ago invented the water-closet, he little dreamt of the great sanitary and agricultural revolution he was inaugurating. We all know upon what trivial events momentous changes sometimes depend; but possibly in the whole history of our material progress no such example of this trite saying can be found than is afforded by the introduction of this useful appliance. Before its introduction the house drains were in no manner connected with the public sewers; the sewage flowed into cesspools which riddled our basements and perpetually gave forth deadly gases, which filled our houses, and killed us with fevers, while the main sewers only took off the surface drainage. They were simply the conductors of the watershed of towns, and any attempt to turn the house drains into them was resisted by the Commissioners of Sewers. The rainfall through them found its way to the river, and the sewage to the land, which was removed at stated times by a service of nightmen, as it is at present in Paris and other large Continental cities, after doing all the mischief it could to the household, and after losing as much as possible of its own virtue for the purposes of the soil. When the hydraulic appliance of Bramah came slowly into operation, the cesspools could no longer hold the largely diluted sewage, and the evil became so great that the custom arose of flushing the house drains into the main sewers. This was clearly contrary to law, but it was winked at by the authorities; it was a great public necessity, in fact, which put all old arrangements aside, and slowly the whole sewage of the metropolis was conducted into the Thames. Those who remember the river thirty years ago can remember a comparatively pure stream, up which salmon used to work to their spawning grounds. Shortly, however, its color began to change from year to year, and at last it became so foul that, in 1859, white paper thrown into the stream was immediately blotted out by the dirty water, and the committee rooms of the Houses of Parliament became unbearable in consequence of the stench it gave forth.

Chief Justice Hale laid it down as law, that "every man was to keep his own dirt at home;" we did this, and probably should have gone on doing so until this day, had it not been for Bramah; he washed it up before our very eyes and noses in the river, and, more disgusting still, he made us drink of it; and forthwith we commenced mighty works to take it down to the ocean. But other towns higher up the valley of the Thames having acquired powers under the newly constituted local Boards of Health, took example by the Metropolis, and transferred their cesspools into the stream, and thus commenced again the poisonous process we have taken so much trouble to abolish. Every day sewage is flowing down into our drinking water from the 800,000 persons located in the valley of the Thames above London. The gross absurdity of thus going to the expense of millions to get rid of our own sewage, that we may have the pleasure of drinking that of the fifty-three towns and villages of the upper Thames, must have struck every one. It is quite certain that the maxim—"every one for himself"—must, in its narrower interpretation, give way to some scheme for dealing with the difficulties thrown upon us by the independent action of local boards having jurisdiction over restricted areas only. The Thames valley, containing perhaps the most important elements of the problem to be solved, has attracted the greatest amount of attention.

Dr. Ackland, of Oxford, has for some time advocated the necessity of appointing some authority to control the catchment basins of rivers, and in conjunction with other gentlemen presented a memorial to Sir George Grey, two years since, with respect to the particular catchment basin of the Thames. The evidence he gives in the report before us of the condition of the river near Oxford is certainly disgusting He states that in one place the deposits of sewage have diminished the depth of the river by 6 feet, a "disengagement of gas takes place at the bottom of the water, and large masses of black sewage which have been deposited are thrown up to the surface," masses of human ordure totally unchanged are seen floating down the river for several miles. Every year the other large towns on the Thames—Abingdon, Wallingford, Reading, Windsor, Eton, Walton-on-Thames, Richmond, Brentford, &c., are obtaining powers to drain into the Thames. Each town thinks only of getting rid of its own refuse, quite regardless of the nuisance it is creating for the other towns lower down the stream. It is quite clear that no genuine system of fluvial purification can be carried out as long as mere local interests are allowed to be consulted.

Mr. Rawlinson, the principal inspector in the Local Government Act Office, who has inspected the rivers of Lancashire and parts of Yorkshire, says, (3993): "They are fouled almost from source of estuary." The rivers Irwell, Medlock, Irk, and the Bridgewater Canal, are more offensive from sewage than the Thames. The Medlock at Manchester is covered with a black scum so thick, that birds are able to walk over it. The rivers and streams in Lancashire and Yorkshire are fearfully abused. There are river beds in those counties that are raised 10 or 15 feet by sewage, ashes, and other refuse. "There are," says Mr. Rawlinson, "bridges under which a dog can scarcely creep, and I have had evidence from inhabitants that they have driven loaded carts under these same bridges." In the neighborhood of Birmingham the streams have been silted up many feet in the same manner. The want of some central authority to deal with the watersheds of districts is illustrated by the case of Salford. The inhabitants of this town wished to carry their sewage by tunnel 3 or 4 miles from Manchester at an expense of £80,000, but were prevented from doing so by the refusal of other towns to co-operate. "Of what use is it," they say, "to expend large sums, when Manchester and all the other towns above will continue to foul the river?" The river at Birmingham contains in dry weather as much sewage as water. Birmingham once boasted of being one of the healthiest towns in England, but this distinction it has long lost, as its mortality is now much higher than that of the Metropolis, and it always suffers from a type of fever. The river Aire, which passes through Leeds and Bradford, is as foul as the Medlock. Passengers crossing the canal in trains are obliged to shut the windows, in consequence of foul air (4115). The Clyde at Glasgow is worse even than the Thames. We might, perhaps, expect to find filth in the rivers of manufacturing towns, but it is observable that places famed of old for hygienic advantages are now being poisoned by the practice of throwing the sewage into the river. The case of Bath is particularly strong. The river Avon, near that city, is nearly a stagnant stream, and is quite poisoned from this cause, and so great is the deposit of sewage in it, that the navigation is impeded. It is not quite so bad at Bristol, as a portion of the sewage of the town is diverted into the tidal river, but the floating-harbor which runs through the old town is quite pestiferous. The perverse arrangements which obtain in many of our watering-places are very observable. In many cases the outlet of the drains is into the sea. The sewage of Exmouth passes, by an open drain, along the foreshore as far as low-water mark, which is within 70 yards distance of the public bathing-place. At Brighton the ladies are subjected to a similar arrangement. At Southsea, again, the mouths of the sewage-pipes open close to the pier, and to the bathing machines. The county surveyor at Somersetshire, who has paid much attention to the drainage of towns, gives a most deplorable account of the condition of some of the western towns. In the rising watering place of Weston-super-Mare all the sewage runs into one of the rhynes or open ditches which drain the marshland of the district. The water in it is so foul that the cattle will not drink it. The river Tone is poisoned by the sewage of Taunton. The river Frome in many places is in a disgusting condition with respest to the water and the deposit along its banks. Indeed, the evidence in this respect gives most abundant proof that our rivers are everywhere being silted up by deposits of cinders and sewage, and that nobody interferes, the reason in many cases being, according to the evidence of Mr. Tom Taylor, the Secretary of the Local Government Board (3897), that the persons who create the nuisance are themselves members of the local boards whose duty it is to conserve them. That it is a nuisance at common law to discharge sewage into a river has been decided, but where it is only a public nuisance there is no one to put the law into operation. When, however, direct injury is done to the property of any individual, local boards can be restrained from polluting streams by injunction. Indeed, several Boards of Health have been stopped in this manner. At Uxbridge, for instance, Colonel Tower obtained an injunction against the board for poisoning his fish in the river Coln with the sewage; at Hitchin the local board was restrained in a similar manner, and so terrified were the members at the penalties threatened by the law, that they resigned, and there is now no board in the town. At Croydon the board have suffered 6 or 7 injunctions, and have been so embarrassed with their sewage that they have absolutely been forced to do what they should have done in the first instance, and which has made them the example to every other town in England—they have turned it on to the land at a profit. When we remember that every farmer is compelled by his lease to consume upon his land all the manure produced upon it, it does seem extraordinary that a reverse rule should obtain when human beings are concerned. And we think we are justly open to the reproach cast upon us by Leibig, who accuses us of wilfully casting forth into the ocean those fertilizing elements we have drawn not only from our own fields, but from those of Europe and the whole world.

But Croydon, we say, has solved the difficulty Bramah has slowly brought about by the introduction of the water-closet. His invention emptied the cesspools into the rivers, and for a time robbed the land; for of old their contents were returned to it in a very disgusting and costly manner. His invention now enables the sewage to carry itself on to the land. At Croydon, being stopped by injunction from throwing the sewage into the Wandle, the local board leased 240 acres of land at £4 an acre, turned their sewage upon it, and relet it for £5 an acre. Thus they make a clear profit of £240 a year, and enormous crops are got off the land, which serves as a pattern-card, as it were, to the surrounding farmers to the value of sewage. Moreover, there appears to be good reason to believe, that at least another hundred acres may be profitably employed, considering the heavy dressings placed on the land by the present tenant. This would yield £340 a year, which would go in diminution of the rates. It is true that Croydon is favorably situated for the distribution of its sewage, as it stands on a height, and it can therefore be distributed by means of simple gravitation; but there are hundreds of towns in England just as favorably placed; and with this example before their eyes, of turning this heretofore considered public nuisance into a source of profit, it is really disgraceful that they should any longer pollute our rivers with it. The importance of the principle of placing entire watersheds under the control of some central board is most clearly set forth in the evidence published in the volume before us, but there appears to be a very general agreement of opinion that the functions of boards appointed for such catchment basins should be merely to supervise the action of the local boards within their district, and to enforce obedience to the law, leaving the necessary works to be carried out by the local boards alone. In short, that fear of centralization which is ever before the eyes of Englishmen, and which has led to evils almost as great in some cases as those it wishes to avoid, is clearly evinced by all those who have given evidence upon this very important subject. The committee in their report have embodied their opinions upon it in the following paragraph:

"We recommend that the important object of completely freeing the entire basins of rivers from pollution should be rendered possible by general legislative enactment, enabling the inhabitants of such entire districts to adopt some controlling power for that purpose; but it should include a provision for compelling local boards to render the sewage of their districts innocuous by application to the land for agricultural purposes. The case of the valley of the Thames (where the purification of the river has been sought by the expenditure of enormous sums, is, to a considerable extent, counteracted by the increased discharge of sewage from towns higher up the stream) requires special and immediate attention."—*The Times.*

On the Elastic Force of Steam. By Prof. POTTER, A.M.*

From the London Mechanics' Magazine, February, 1865

The following article is an examination of the applicability of Mr. Alexander's formula for the elastic force of steam, to the elastic force of the vapors of the liquids as found by the experiments of M. Regnault.

To those who are investigating the development of the mechanical force which arises from the action of the subtle agents causing the phenomena of heat, electricity, magnetism, &c., upon dense matter, the law of the elastic force of vapors in contact with the liquids from which they arise, at different temperatures, is a subject of great importance.

Many formulæ have been proposed for the elastic force of steam, which corresponded sufficiently nearly with the observed results through moderate ranges of temperature, but failed completely for great ranges. It is not intended in the present paper to recapitulate these attempts.

M. Regnault has given formulæ for interpolation which enabled him, from his observation through many series of experiments, to construct most valuable tables of the elastic force of the vapors of the liquids in regularly ascending temperatures. These are found in his treatise "Relation des expériences . . . . pour déterminer les principales lois et les données numériques qui entrent dans le calcul des machines à vapeur. Par M. V. Regnault," in two volumes, of which vol. i. is tome xxi., and vol. ii. is tome xxvi. of the Memoirs of the Institute, but the two volumes can be procured as a separate treatise; and from a recent paper in the *Philosophical Magazine* they appear not yet to be much studied in this country.

However valuable interpolation formulæ may be for the purposes to which they are applied, yet in physical inquiries we naturally seek for formulæ which are likely to represent the physical laws of the phenomena; which will generally be simpler than the expansions in series with coefficients to be determined from the experiments, which is the constitution for the interpolation formulæ.

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* Communicated by the author, to the *Philosophical Magazine* for February, 1865.

In the number of the *Philosophical Magazine* for January, 1849, there is an important paper, reprinted from *Silliman's American Journal of Science* for September, 1848, and entitled "On a New Empirical Formula for ascertaining the Tension of Vapor of Water at any Temperature. By J. H. Alexander, Esq." In this paper is a table occupying four pages, in which the results of the formula are compared with the observations of Regnault, 1844; the Franklin Institute, 1836; the French Academiciaus, 1829; Taylor, 1822; Arzberger, 1819; Ure, 1818; Dalton, 1801 and 1820; Southern, 1797 and 1803; Bétancourt, 1790; Robison, 1778; and Watt, 1774. Though the formula shows considerable differences from even the more recent experiments in some cases, yet the differences are not more than are found between the experimental results themselves of the different observers at nearly the same temperatures. As the range of temperature is from — 27°·112 to 435°·227 Fahr., through which the general accordance of the formula with the experiments holds good, we must admit the argument of Mr. Alexander, that his formula accords with the observations of the different observers as closely as they accord with each other, to be conclusive.

When we consider the formula, we can see that the nature of the experiments must be such that extreme accuracy is unattainable with even the most improved apparatus. When p is the elastic force of the vapor expressed in the pressure of a column of inches of mercury, t the temperature expressed in Fahrenheit's degrees, then Mr. Alexander's formula is $p=\left(\frac{t}{180}+\frac{990}{1695}\right)^6$. The binomial being to the sixth power, a small error in the value of t, either in the graduation of the thermometers or in the observations, produces a considerable change in the value of p; and if both errors existed at the same time and in the same direction, the error in the value of p might become large. We have no need to be surprised that even the results of M. Regnault require this consideration to be kept in mind, and it is the general accordance through long rangès of temperature that we must look for, rather than great accuracy at all points, which the subject is not capable of giving.

Having long ago compared Mr. Alexander's formula with the results for the elastic force of several vapors given at page 298 of Dalton's "New System of Chemical Philosophy," part 1st of volume ii., and found the accordance satisfactory, I have lately undertaken the comparison with M. Regnault's results in the second volume of his *Relation des Experiences*, &c., pp. 374 and forwards. The result of these investigations is contained in the following remarks.

To adapt Mr. Alexander's formula for the elastic force of steam to that of the vapors of other liquids, let p be the pressure, let a and b be constants, and t the temperature, then we have

$$p=(a+bt)^6.$$

Now, M. Regnault's results give p in columns of millimetres of mercury, and t in Centigrade degrees; so that I shall give the procedure and results in these terms at first, and afterwards show the formulæ for p in inches of mercury, and t in Fahrenheit's degrees.

For *vapor of alcohol*, in the formula $p=(a+bt)^6$, putting $t°$ C.$=0$, at the freezing point of water, M. Regnault found

$$p = 12{\cdot}70 \text{ millims.} = a^6;$$
$$\therefore a = 1{\cdot}527451.$$

Again, at 150° C. he found

$$p = 7318{\cdot}40 \text{ millims.} = (1{\cdot}527451 + 150b)^6;$$
$$\therefore b = {\cdot}0191920.$$

With these values in the formula $p=(a+bt)^6$ the numbers in the third column of Table I. were calculated; the second column contains M. Regnault's corresponding results, from his table at page 374 of vol. ii.

TABLE I.

Temperature Centigrade by air-thermometer.	Elastic force of vapor of alcohol by interpolation formula.	Calculation by Alexander's formula.
Deg.	Millims.	Millims.
— 20	3·34	2·237
— 10	6·47	5·674
0	12·70	12·700
+ 10	24·23	25·836
20	44·46	48·748
30	78·52	86·556
40	133·69	146·166
50	219·90	236·651
60	350·21	369·665
70	541·15	559·887
80	812·91	825·507
90	1189·30	1188·750
100	1697·55	1676·423
110	2367·64	2320·517
120	3231·73	3158·836
130	4323·00	4235·640
140	5674·59	5602·368
150	7318·40	7318·395

The general accordance of the second and third columns through the range of 170° Centigrade is, I think, sufficient to warrant the conclusion that the elastic force of the vapor of alcohol is represented by the formula $p=(a+bt)^6$; and further research might furnish values of a and b which would produce greater accordance.

For the *vapor of ether*, taking the temperatures $t°$ C.$=0$ and $t°$ C.$=100°$ to find the values of a and b in the formula $p=(a+bt)^6$, we find

$$a = 2{\cdot}385739,$$
$$b = {\cdot}01742984,$$

TABLE II.

Temperature Centigrade by air-thermometer.	Elastic force of vapor of ether by interpolation formula.	Calculation by Alexander's formula.
Deg.	Millims.	Millims.
— 20	68·90	71·471
— 10	114·72	116·964
0	184·39	184·390
+ 10	286·83	281·500
20	432·78	417·937
30	634·80	605·528
40	907·04	858·585
50	1264·83	1194·238
60	1725·01	1632·774
70	2304·90	2198·009
80	3022·79	2917·681
90	3898·26	3823·840
100	4953·30	4953·296
110	6214·63	6348·050
120	7719·20	8055·800

which give the results in the third column of Table II.; and the second column contains M. Regnault's corresponding results, from his table at page 393, vol. ii.

The general accordance of the second and third columns through a range of 140° C., for so volatile a liquid as ether, is, I think, sufficient to show that the elastic force of its vapor is represented by the formula $p=(a+bt)^6$.

TABLE III.

Temperature Centigrade by air-thermometer.	Elastic force of vapor of sulphuret of carbon by interpolation formula.	Calculation by Alexander's formula.
Deg.	Millims.	Millims.
— 20	47·30	50·240
— 10	79·44	81·634
0	127·91	127·910
+ 10	198·46	194·245
20	298·03	287·066
30	434·62	414·231
40	617·53	585·230
50	857·07	811·400
60	1164·51	1106·146
70	1552·09	1485·185
80	2032·53	1966·785
90	2619·08	2572·043
100	3325·15	3325·144
110	4164·06	4253·690
120	5148·79	5388·924
130	6291·60	6766·143

For the *vapor of sulphuret of carbon*, taking the temperatures $t°$ C. $= 0$ and $t°$ C. $= 100°$, we find the values of a and b in the formula $p = (a + bt)^6$ as follows:

$$a = 2{\cdot}244660,$$
$$b = {\cdot}01618729,$$

which give the results in the third column of Table III., M. Regnault's corresponding results (from his table at p. 402, vol. ii.) being given in the second column.

The general accordance of the second and third columns is again sufficient to lead to the conclusion that the vapor of sulphuret of carbon has its elastic force represented by the formula $p = (a + bt)^6$.

For the *vapor of hydrochloric ether*, determining the constants a and b in the formula $p = (a + bt)$ from the experimental results at the temperatures 0° C. and 100° C., we find

$$a = 2{\cdot}783579,$$
$$b = {\cdot}01753492,$$

which give the results in the third column of Table IV.; and M. Regnault's corresponding results, from his table at page 446, vol. ii., are given in the second column.

Table IV.

Temperature Centigrade by air-thermometer.	Elastic force of vapor of hydrochloric ether by interpolation formula.	Calculation by Alexander's formula.
Deg.	Millims.	Millims.
— 30	110·24	132·374
— 20	187·55	207·360
— 10	302·09	314·829
0	465·18	465·180
+ 10	691·11	671·130
20	996·23	948·035
30	1398·99	1314·236
40	1919·58	1791·426
50	2579·40	2405·017
60	3400·54	3184·566
70	4405·03	4164·196
80	5614·11	5383·030
90	7047·51	6885·700
100	8722·76	8722·754

The general accordance of the second and third columns warrants us in concluding that the elastic force of vapor of hydrochloric ether is expressed by the formula $p = (a + bt)^6$.

M. Regnault's experiments on the elastic force of the *vapor of essential oil of turpentine* extend from 0° C. to 200° C., and by calculating the constants a and b from the pressures at 0° C. and 100° C., the formula does not well accord with the observations; and taking the observations at 50 °C. and 150° C. to determine the constants, the results of calculation and observation diverge greatly also; but taking the pressures at the temperatures 100° C. and 200° C. to determine a and b, the formula shows a general accordance with the results of observation, with, however, occasional differences of considerable magnitude. These latter give

$$a = 1{\cdot}029373,$$
$$b = {\cdot}01224551,$$

with which the results in the third column of Table V. were calculated; and M. Regnault's corresponding results, from his table, page 501, vol. ii., are given in the second column.

TABLE V.

Temperature Centigrade by mercurial thermometer.	Elastic force of vapor of oil of turpentine by interpolation formula.	Calculation by Alexander's formula.
Deg.	Millims.	Millims.
0	2·07	1·190
10	2·94	2·335
20	4·45	4·281
30	6·87	7·425
40	10·80	12·294
50	16·98	19·574
60	26·46	30·140
70	40·64	45·084
80	61·30	65·750
90	90·61	93·772
100	131·11	131·110
110	185·62	180·092
120	257·21	243·458
130	348·98	324·406
140	464·02	426·640
150	605·20	554·419
160	775·09	712·615
170	975·42	906·760
180	1207·92	1143·114
190	1473·24	1428·722
200	1771·47	1771·470

Though the differences in the above table are in some cases large, yet I think the general accordance of the second and third columns is sufficient to warrant our concluding that the elastic force of vapor of oil of turpentine is expressed by the formula $p = (a + bt)^6$. This last example shows that it is not safe to take *any two* observed pressures and temperatures for the purpose of determining a and b from the tables, but the values obtained should be applied to the other temperatures and pressures before we can rely upon them.

As the computations are tedious, I shall not proceed further at present with the numerous vapors examined by M. Regnault, having satisfied myself that the elastic force of the vapors generally is expressed by Mr. Alexander's formula.

For the six liquids of which the elastic forces of the vapors have now been shown to be expressed by the formula $p=(a+bt)^6$, we have the following formulæ for p expressed in inches of mercury and t in Fahrenheit's degrees:

For *steam* or vapor of water (Mr. Alexander's formula in decimals),

$$p=(\cdot5840708+\cdot00555555\,t)^6.$$

For vapor of *alcohol*,

$$p=(\cdot691898+\cdot0062885\,t)^6.$$

For vapor of *ether*,

$$p=(1\cdot210775+\cdot00564785\,t)^6.$$

For vapor of *sulphuret of carbon*,

$$p=(1\cdot141374+\cdot005245224\,t)^6.$$

For vapor of *hydrochloric ether*,

$$p=(1\cdot441730+\cdot005681901\,t)^6.$$

For vapor of *oil of turpentine*,

$$p=(\cdot4734178+\cdot00396796\,t)^6.$$

Fresh researches would probably lead to small modifications of the values of the constants, but I do not think that large changes would be found necessary.

Facts and Fallacies as to Tubular Boilers.

From the London Practical Mechanic's Journal, February, 1865.

Steam boilers—crude, ugly, inefficient, wasteful, and unmanageable, as they so generally prove—are yet amongst the most important material things to which an Englishman's mind can be directed; for, upon these big kettles, as the Germans literally call them, has depended a good deal of the national prominence of position and power we hold in the world, and a far larger proportion of British greatness must, year after year, be found dependent upon these unwieldy utensils.

Any competent man who will say a word of new truth on such a subject, should be accepted on all sides with the gratitude that becomes a benefactor, large or small; but if the subject be thus important, in the like proportion is the man who rushes in and, by ill-considered assertion or misinterpreted experiment, "darkens counsel by words without knowledge," deserving of deprecation.

Especially is this so when such communications come from one whom the half-educated, who constitute the mass, in some way accept as an authority, whether justly or unjustly we will not now enquire.

These remarks have been suggested to us by the perusal of a pamphlet (a work, probably, we ought politely to call it) by Mr. Charles Wye Williams, published by Spon, London, "On the Steam Generating Power of Marine and Locomotive Boilers."

The production consists of but 25 quarto pages, and, although we nowhere gather such to have been the fact, was probably originally a paper read before some provincial society; yet within an equal number of pages we think it would be difficult to compress a greater amount of ignorance of physics, and misinterpretation of experimental facts.

And yet the subject is one of the simplest character, and one upon which not only have all capable mechanical engineers long possessed well-defined ideas and clearly settled conclusions, which they act upon every day of their lives, but which are day by day proved to be true, by the tests of actual practice.

Were it not that Mr. Williams has acquired a sort of quasi-scientific reputation as a great Prophet of Smoke, we should not have thought it worth while to notice this last product of his very ready pen at all, content to let it, of its own weight, drop into that oblivious place where all error finds itself at last.

We recollected, however, that when a former, and, if we mistake not, the ante-penultimate production of Mr. Williams' pen, his "Heat in its Relation to Water and Steam," in 1862, made its appearance, there were a good many who might have been expected capable of appraising it at its just value, but who were, for a time at least, staggered and uncertain as to one or to all of the many astonishing misconceptions of physics with which that work abounds, and who really seemed to think that perhaps a prophet had risen up amongst us so profound that his utterances were as yet not understood fully of the uninitiated. In fact, there is a certain sort of philosophy that has a positive tendency to muddle other men's brains.

This present *brochure* of Mr. Charles Wye Williams is precisely of that sort and quality, and hence it is not amiss to analyze and point out briefly its leading mistakes. The first chapter, "On the Assumed Value of Tube Surface," begins thus: "It will doubtless hereafter be a matter of special wonder, when the construction of boilers shall have been perfected, to find that for 34 years, since Stephenson's *Rocket* won the prize for the locomotive, we have been following an *ignis fatuus*—the so-called heating surface of tubes; and that so far from that surface being the measure of the heat-transmitting and evaporative power, it may, in fact, be altogether omitted in our calculations, and for the measure of that power we shall have to look to a different part of the boiler—a portion hitherto absolutely unnoticed and unappreciated by engineers. The experiments and proofs hereafter detailed fully establish this fact beyond question."

So far the statement is that the tubes of tubular boilers (locomotive or marine) are, as a means of conveying the heat of the products of the burnt fuel to the water, absolutely valueless.

The next paragraph surpasses our comprehension as to any distinct idea it conveys.

"Of the tube internal surface, as regards its heat-transmitting and steam-generating property, we may, as will hereafter be shown, on the authority of the late Mr. Dewrance and Mr. Hick, of Bolton, estimate its efficiency in comparison with that of the furnace or fire-box plates at but one-tenth of the gross nominal surface it presents, where the tubes are not more than six feet long. My own numerous experiments and observations fully bear out this statement." "Again, when the tubes are ten feet long and upwards, we will not err much if, with the exception of the first *twelve inches*, we leave them altogether out of our calculation, and regard them as mere conduits for conveying the heated products of combustion to the chimney."

So, then, with tubes of 6 feet long, ten super. feet of tube is equal to one of fire-box; but tubes of any greater length, however great their total surface, we may consider as worth nothing, except the first foot of their length, and leave all the rest out of calculation altogether!

So far for the *ignis fatuus* that engineers have been foolishly relying upon for 34 years as having something to do with the steam raised in locomotives, &c.; such is their sin of commission, according to Mr. Williams. Let us now come to their sin of omission—" the portion of the boiler which has been absolutely unnoticed and unappeciated by engineers."

Here we have it. " Against the insufficiency of the tubes, as heat transmitters and steam generators, we have the hitherto neglected surface of the *face-plate*, presenting a face to the direct action of the hot current of the furnace. Assuming the orifice of the tubes occupy one-fourth of the gross area of the face-plate, the practical heat-transmitting portion will be the remaining three-fourths."

" Hitherto the face-plate has been regarded as a mere mechanical contrivance by which the tubes were held in their places, for preserving certain distances between them, to enable the water to surround them.

" Strange to say, no idea whatever appears to have been entertained that the face-plates had any heat-transmitting or steam-generative property *of their own*."

To many of our readers the term *face-plate* will be new and without a distinct meaning. We may, therefore, here say, that the author's *face-plate* means that side of the fire-box of a boiler on the locomotive construction through which one end of the tube passes.

In Mr. Williams' *strict* sense, it is only that portion of the plate forming this side of the interior of the fire-box which is not cut out by the perforations for the ends of the tubes. It is, therefore, the unperforated surface of the tube-plate of the fire-box. We may therefore at once dispose of the sin of omission charged against locomotive and other engineers by declaring it simply a mare's nest.

It is not a fact that *any part of the interior surface* of fire-box in locomotive boilers has been unnoticed and unappreciated by engineers. We could point to scores of examples, were it necessary so to support the universal cognizance of all those engaged in proportioning such boilers, proving that *all parts* of the interior of the fire-box, every square inch of its surface, is and always has been habitually taken into calculation, and its effect allowed for; and hence this tube-plate, or *face-plate*, as Mr. Williams is pleased to call it, as a matter of course, included.

Although he does not say so in words, Mr. Williams is obviously of opinion that this *face-plate* does nearly all the work of the whole fire-box; or, to be strict, so as to avoid injustice, he distinctly infers that each square foot of interior surface of this face-plate (at a given level in the fire) is vastly more effective than any equal area of any other of the three sides of the fire-box, or of its roof.

"We here at once recognise the cause of the great steam generative power of the *single face-plate* in each locomotive, namely, the almost electric rapidity of the draft of the chimney, producing a correspondent increase in the force with which the heated current strikes that plate."—Page 4.

And a little further on—"The effect produced by the direction in which the heated current strikes the surface may aptly be compared to the rolling of a cannon ball rapidly along a sheet of ice, as compared with letting it fall vertically upon its surface. The simile is perfect; for in proportion as the rapidity of the motion of the ball along the plane of ice is increased, so will its effect be *diminished*, whereas, as the rapidity with which it falls is *increased* so also are its effects."—Page 5.

Alas for the men who bring *similes* into science. Here is the old blunder in mechanics—the attempt to compare *pressure* with *vis-viva*. The *effect* of the ball rolling along the ice is simply equal to its weight, and the pressure due to its weight upon the ice in contact with it at any instant will be the same, whether the ball roll fast or slowly. Mr. Williams' proposition involves this exquisite mechanical consequence, that the ball *loses weight* in proportion as it rolls faster, and that if it rolled with an infinite velocity it would cease to have any weight at all. Again, as the ball rolling along the ice has no vertical velocity at all, *i.e.*, is, as regards the vertical, absolutely at rest, we are somewhat at a loss to see how we can compare its vertical *effect* on the ice with that of a like ball dropping with more or less vertical velocity upon the ice. In a word, how we are to compare the weight of the ball with its weight multiplied by the square of its vertical velocity, M, with MV^2, where, by the conditions, we cannot get rid of V on the one side, and it cannot exist at the other.

But we make no doubt all this would seem very undemonstrative to the author, so we will pass to the use he makes of it as a *simile*.

He obviously is of opinion—indeed he distinctly affirms what amounts to this—that a given volume of heated air of given density arriving at and passing off from a given plane surface of a body of constant temperature and receptive of heat from it during a given time, must communicate more of its heat in this time, if the direction of motion of the heated air be perpendicular, than if it be parallel to the receptive surface.

Now, to fix our ideas, let us just ask Mr. Williams this question: Suppose a square tube of cold boiler plate, of 10 feet long by a foot square, placed in a vacuum, and that a red-hot cannon shot of say 1 pound weight were to pass along the axis of the square tube at the rate of say 1 foot per second.

He would *perhaps* admit that the total heat lost to the ball and received by each of the four sides (two vertical and two horizontal) of the tube would be the same. Let us call this quantity for any one side, on the unit of surface (1 square foot)=10.H.

Now, suppose a boiler plate of 1 foot square, of like thickness and temperature, to be passed parallel to itself, through the tube and square to its axis, at the rate of 1 foot per second, and always in a position 6 inches in advance of the red-hot shot.

We ask, would not the total heat delivered into this square foot of plate be also exactly =10·H., assuming, as we must do, that the difference of temperature at the commencement between the shot and the plate remained constant?

Now, the shot here is the representative of any one of the particles of hot air that move against the face-plates and through the tubes parallel to their interior surfaces.

To be brief, Mr. Williams confuses *radiation* and *convection.* The former has nothing to do with position, except as regards the angle made with the ray by the receptive surface; upon the latter (in the matters before us) depends the question of how many radiating particles are carried per unit of time within the same mean distance of the receptive surface.

This confusion of thought is made quite unmistakable by a passage of page 10. After having taken to task Mr. Clark and Mr. Z. Colburn, who, in his excellent work on Locomotive Engineering, has sinfully ignored these wonderful properties of "face-plates," the author proceeds:

"In his work, Mr. Colburn speaks of a 'generator in which the heated products of combustion are split up into numerous streams by tube-flues.' The supposed value of this splitting of the heated products of combustion into numerous streams is based on a serious mistake in supposing that those small attenuated streams had the faculty of giving out heat laterally to the course of those streams.

"Now, it is well known that rays of heat or light do not radiate *laterally to their course*, and that their effect depends on their striking in a vertical direction, or as near to that as possible. As well might we suppose that the rays of the setting sun, as they pass beside us, on the line of the earth's surface, . . . were equally powerful with those that strike downwards with vertical force at noon; or that a cannon ball glancing along the side of an iron-clad steamship, and in the line of its iron plates, would have equally destructive force with one striking in a point-blank direction and vertical to those plates."

The italics above are ours. We pass by the confused use of the word vertical, intended no doubt for perpendicular to the course of the ray, although the appeal to the vertical *sun* does seem to suggest a suspicion that the writer fancies perpendicularity to the horizon has something to do with radiation; and by the words in italics we see at once that he confounds the *direction of radiation from the particles* of a stream of heated matter, with the *direction of motion of the stream itself.*

Is it true that there is no radiation of heat from and perpendicular to the sides or top of a stream of liquid cast iron, or that there is not just as much radiated from an unit of surface, perpendicular to the direction of motion of the stream, as there would be from the same unit of the square advancing end of the stream, were it practicable to so arrange it? If so, then let us revert to Mr. Williams' own example—the sun—and ask him what is the cause of the *diffused* light of day?

It is wearisome to dissect this sort of stuff. Mr. Williams has not thrown any light on the subject of the locomotive boiler. From at least the year 1834, if not earlier, the fact was clearly ascertained and recognised that, unit for unit of surface, the fire-box was greatly more efficient in passing heat into the water than the tubes. It is so for many reasons, mainly because the receptive surfaces of the fire-box are, as respects *radiation* from the incandescent fuel, much *nearer* to particles at the highest temperature than any other part of the boiler, and the effect of radiation is greater inversely as the *square of the distance*, and as respects *conduction*, because the plates are here in actual contact with white hot coke.

It has also never admitted of a question, on the part of any competent engineer, that as respects *convection*, each square inch of the various parts of the interior of the fire-box is more effective, in proportion as a larger volume of gases, heated to a given temperature, passes it by or reaches it in whatever direction in a given time. From this last it is no doubt true, that all that part of the fire-box towards which the heated gases of the fire pass in order to enter the tubes, must have more heat brought to them in a given time than to the opposite parts nearer the fire-door. But that is all, and does not specially or solely apply to the tube-plate (or face-plate of Mr. Williams); it is equally true, *pro tanto*, of the roof of the fire-box.

To jump to the conclusion from this, that the tube-plate does all or nearly the whole of the work of the whole interior of the fire-box, is simply nonsense. To endeavor to sustain such a notion by misinterpreted experiments and ill-understood physics, is to indicate an incapacity for dealing with such questions at all.

The comparative small efficiency of the tubes, again, has been for years fully recognised and understood. It mainly arises from the facts—first, that the temperature of the particles of the radiating streams of heated gases swept through them is greatly below that of those particles while in the fire-box (where they are robbed of much of their heat); and, secondly, that the draft is obliged to be so sharp, in order to maintain the high temperature of the fire, that there is not *time* enough during the transit through tubes of ordinary length for the gases to radiate all or even the greater part of their heat.

This is proved by the tremendous temperature of the smoke-box and even the top of the funnel of every locomotive; and, to any sane man, this fact is an argument cogent and inexpugnable for lengthening out the tubes, so as with the same velocity of draft to give *more time* for radiation within the tubes.

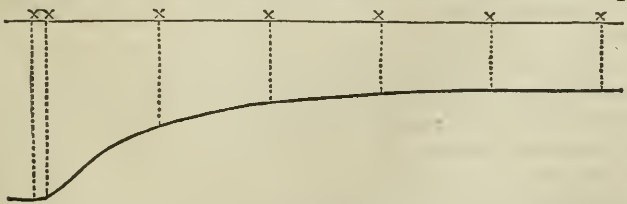
And here comes in the second and most extraordinary error, namely, that only the first few inches of the tubes are of any use whatever, and that in place of lengthening we should shorten them.

To put in its true light this fallacy, we need do no more than reproduce here Mr. Williams' own first experiment. He had a boiler constructed in which a *fasciculus* of tubes 5 feet in total length was separated by plates at intervals, so that, he says, "the heat-transmitting value of each lineal foot of the tube would be indicated." The compartment next to the *face-plate* was only one inch in length, the second was 10 inches in length, and the four subsequent ones were 12 inches in length each. After three hours work, the following quantities of water had been evaporated from

		Lbs.	Oz.
Compartment	No. 1 (1 inch long) . .	2	14
Do.	No. 2 (10 ") . .	2	15
Do.	No. 3 (10 ") . .	1	14
Do.	No. 4 (12 ") . .	1	6
Do.	No. 5 (12 ") . .	1	2
Do.	No. 6 (12 ") . .	1	1

We take it that every one will see that the first compartment of 1 inch long is in reality not that of an inch of tubes only, but of the face-plate or tube plate surface also. In fact, the heat taken up by the relatively large mass of metal in the tube-plate next the fire is rapidly given up to the water in contact with it and the first inch of tube. And were it worth while to expend space in further quotation we have proof in the facts given, how much, in this first compartment, the action of tube and tube-plate are confounded.

We shall pass by also, what most persons will perceive, that horizontal tubes thus diaphragmed off into a number of separate chambers are no longer in the same, or in as favorable a position, as in an ordinary boiler where the *water is free to circulate* in all directions, and to sweep *along* the tubes from the cooler to the hotter end, in the *reverse direction* to the current of heated gases passing through them. We simply propose to plot into a curve, as below, the author's own result; and let any man ask his own eye if this curve (which represents the efficiency, admitting Mr. Williams' condition, in relation to the length of the tubes) does not conclusively prove, that after the first three or four feet in length from the fire, the total effect of the tubes is *almost directly as their length, and as the residual temperature*



of the passing currents of heated gases. In fact, for the last three feet, the absorption of heat from each foot of the tube is very nearly uniform, almost quite so for the last two, and would obviously have proved still more so had the tubes been prolonged for three feet further. Yet, in the face of this obvious deduction from his own experiment, what is Mr. Williams' conclusion? "Here we have an unquestionable confirmation of the valueless character of the last four feet of the tube." We may let this speak for itself.

It would be tedious and demand space we can better appropriate, to persue the remainder of these pages through the ill-devised or misinterpreted experiments with short tubular boilers, put after each other in succession, with spaces or combustion chambers between. They are but complications of the primary mistakes, and not worth disentangling. Nor need we show the want of foundation of what is pompously termed the "Law for Regulating the Applications of the Face-plate Surface," this *law* being, that (in *all* boilers, as we understand him, locomotive and marine) we are to provide one square foot of effective face-plate surface for an equal area of grate surface. The magnificent title of a *law* is fitly commented by the nearly concluding sentence of the chapter. "How far this law may hereafter be modified, will be the result of future practice."

That practice should be determined or modified by law, (natural law,) we have always thought; but that a natural law should be modified by practice, and that it should be uncertain how far it may be modified (even to zero perhaps) by practice, does to us sound a little paradoxical.

The remaining two chapters of this production we shall pass wholly, viz: "On the Application of the Steam in aid of the Draft," and "On the Use of Coal in Locomotive and Marine Boilers." They have no direct concern with what has preceded them, and their "stuff and substance" might be not unjustly indicated in the words of Blumenbach, as applied to phrenology with a slight alteration: "There is little in them that is new or true, and that which is new is not true."

The practical upshot (if there be any) of Mr. Williams is, that tubular boilers should be constructed of consecutive drums of short *fasciculi* of tubes, arranged with delaying spaces or combustion chambers between them. This is, in fact, what he means by his "law of the face-plate." Within certain limits, but for reasons widely different from anything that Mr. Williams has advanced, we have little doubt that by such a method, *where practicable*, not only the total surface but the efficiency of the unit of parts of the surface in some tubular boilers may be increased.

In this there is nothing new whatever. Large tubular land and even marine boilers may be at this moment pointed to, that have been a considerable time at work, and which consist of a succession of large drums of tubes with combustion chambers between each, and the fire at one or even at both opposite ends. In these the velocity of the draft is moderate. If this velocity *must inevitably* be rapid and cutting, as in the locomotive boiler, then such breaks in the length of the tubes are, for various reasons, *impracticable*—physically so, because they destroy the rapidity of draft by their increased resistance;—mechanically, because inadaptable to the necessities of structure in the locomotive engine.

As for marine boilers, the day will come when fresh water alone will be employed, and then the directions for improvement will be to follow, as far as possible, in the track of the boiler of the locomotive.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Work and Vis-viva. By De Volson Wood, Prof. C. E., University of Michigan.

The object of this article is to make some comments upon one published by Mr. Nystrom, upon the same subject, in the last March number of the *Journal.* Had he not grossly misrepresented me in at at least two points, in his criticism upon a former article of mine, it would hardly be necessary for me to reply to him, for I observe that his reasoning upon all the new matter of the article, is remarkably correct, and his ideas more definite, agreeing essentially with mine, and hence, as he observes, with the standard authors of the day.

He opens upon me with a masked battery in the form of an explanation, and then pours in a cross-fire in the form of cant phrases, until the casual reader might suppose that my arguments were annihilated; but the sequel will show that he has merely exposed his position at several vulnerable points, no one of which can stand a fierce assault.

He says, I have misconceived the meaning of the letter V, and says it means *mean* velocity. I willingly accept the explanation, but am I to blame for the misconception? Did he so limit it in the preceding article? Did he not use it at one time as a constant, and at another as a variable, without any mention of the double usage? And if so, does it tend to avoid "the great confusion which now involves the subject?"

In the next paragraph he makes a correction, which I gladly accept. I should have said in the case referred to, that the work $= \frac{1}{2} F V T$.

In the following paragraph he thinks that my expression "$F T = S$," should be $F V = S$. Mine is evidently a misprint, and I presume his is also; for it should be $V T = S$.

Having cleared up these minor points, we proceed to the more important criticisms.

I have said, and he quotes the same, on page 181, that the equation $F V T = M V^2$ is a true equation without expressing the value of work. Then the writer adds: "Is it possible that the formula can be a true *equation of work,* without expressing the value of work?" In this he plainly intimates that I have called it "a true equation of work." Have I said so? Has my language *intimated* it? Is not this putting words into my mouth, and then taking advantage of them? Is it making a fair representation of my meaning? He then says: "I (Mr. Nystrom) contend that it expresses the true relation between work and *vis-viva,*" and afterwards proceeds to prove it. Let us see how he proves it. He commences the proof in the latter part of page 183.

He takes the case of a body free to move and acted upon by a constant force F, during a time T, at the end of which it has acquired a velocity V. He then truly finds $FVT =$ *twice* the work done upon the body. See equation 7, p. 184. If, now, M be the mass of the body, moving with the velocity V, MV^2 equals twice the work. See equation 8, p. 184. It also equals the *vis-viva*, as he says a few lines below. Hence, in the equation $FVT = MV^2$ one member *is the vis-viva*, and the other *is not the work ;* does it then express the true relation between work and *vis-viva ?* and if not "whose reasoning must be very elastic ?"

In regard to this equation the writer says, p. 184, that I "proved it to be '*an absurdity under every hypothesis.*'" Now, by referring to my article, p. 27, present volume, or even to his extract of it as given on p. 181, it will be seen that he has omitted the phrase, "except the first," which should immediately follow the above quotation; and hence would read, "*proved to be an absurdity under every hypothesis except the first.*" What was this *first hypothesis ?* It was "that the body be free to move, and acted upon by a constant force." An examination of Mr. Nystrom's article, pp. 183 and 184, shows that this is *the very hypothesis* which *he* has used in establishing the equation under consideration. I leave it for the careful, candid reader to judge "whose reasoning must be very elastic." This may be a sharp way of showing up a writer, but is it the way "to advance cautiously?" Does it aid in removing "confusion ?" Does it savor of that "due deliveration" which is essential to true "reform ?"

It should be observed, still further, in regard to this equation, of which so much has already been said, that it is a true equation only when the body is free to move, and under a constant force. If the force varies as the distance, square of the distance, or inversely as the distance from some point, then it will not be true. So Mr. Nystrom gives a differential expression for work, on p. 184, which is

$$dW = F\,v\,dt,$$

the integral of which gives the work. Letting G be the acceleratrix, and he makes $v = Gt$. Is this true, except when G is constant ? and if not, is the expression

$$W = \int F G\,t\,dt,$$

on p. 186, true when F and, consequently, G is variable ?

Will we find by solving it that the figure of work, when the force varies as the square of the velocity, is a regular pyramid, with right lines for its edges ?

Is not momentum the *mass* multiplied by the velocity ? and if so, should not the expression on p. 186 be

$$\text{Momentum, } \frac{M}{g}V = \int V\,dt,$$

in which M is the *weight* of the mass ?

On p. 183 he says: "It is perfectly absurd to say with myself and others '*that work is independent of time.*'" Why, then, does Mr. Nystrom say on p. 327, vol. xlviii, that "the foot-pounds of work means so many pounds raised through a space S, *independent of the time.*" But now he tries to show the absurdity by begging the question, and reasoning from my stand-point. He says, according to my reasoning "force is independent of work," &c.; but I suppose he means that *work is independent of force*, and adds, "a force of one pound can accomplish as much work as a force of 100 pounds; but at the expense of time and velocity only." This is true, and is no more than I contended for, which was, that the work is always the same when the expression F S gives the same quantity, whatever be the relation of F and S, or V and T. Will the writer contend that because he contracts to dig a canal in six months, and completes it in three months, that, therefore, he has done only one-half the work? Have I *intimated* that "space cannot be accomplished without time and velocity?" I gave it as my *impression* that F S is the *primive* formula for work; but have I objected to the expression F V T, when V is constant, or $F\,v\,dt$ when F is variable? In my article in the February number of the *Journal* for 1864, on p. 89 may be found the very equation which he has so freely used.

Is it necessary for Mr. Nystrom to resort to the elementary, although it may be a profitable exercise of "drawing chalk-lines upon a blackboard," in order to convince him of what no one calls in question?

With regard to the term "mechanical power," or simple "power," which is represented by $F\,v$, I have raised no issue.

Students are familiar with the term, and all I wish to contend for is, that it is of the same *quality* as work, and that it is *the work* done in a unit of time under a constant velocity. In my last I expressed the desire that the term power might be restricted to this expression.

Let us see what results from Mr. Nystrom's stand-point. He says, p. 183, that "power is the differential of work." Do we not rightly infer from this that power is a part of work, an infinitesimal portion of it, and hence of the same kind or quality as work? Again, he says "F V T is the expression for work." Now, if $T =$ one second, minute, or hour, do we not have $F\,V =$ *the work* which is done in a unit of time? which is also the mechanical power. Then is not the mechanical power THE WORK done in a unit of time? Is not this "the difference between power and work?" Again, if $V = 1$ and $T = 1$, the expression becomes $F \times 1_{vel} \times 1_t$; which is THE WORK DONE in a unit of time and unit of space; may not the English horse-power be the unit of work, even if it be the unit of power? According to this analysis, is not the unit of power *a unit* of work?

If this view be correct, and it follows immediately from his equation, is it true that "the difference between foot-pounds of power and foot-pounds of work, is the same as the difference between square feet and cubic feet?" (See p. 188.)

On page 187, he says: "The substance of the so-called moment of inertia MR^2, is work when n is constant." How does this compare with what he has said before? Do we have the essentials of velocity and time in it?"

Mr. Nystrom has not criticised the article referred to in the November number of this *Journal* for 1862, more severely than I would. I used the word force in connexion with momentum and *vis-viva*, as it is popularly used. Mechanics say "the force of momentum," and mechanical writers say "living force." I do not defend the use of the terms, but, having accepted them, I see no reason for changing my views of the essential character of the *things* represented by them, call them what you may. A careful study of the article in the February number of 1864, would have made one or two of his criticisms unnecessary. I will pass over many important points, and modestly inquire, *where is his true reform?* I confess I do not see it, but trust I shall when he "brings it bodily out to sight."

For the Journal of the Franklin Institute.

On the Use of the Double Eye-piece in the Determination of the Personal Equation. By S. W. Robinson, C.E.

What is designed to be understood by the double eye-piece, in contradistinction to the binocular eye-piece is, that the former is designed for the use of a single eye of two observers, while the latter is intended for the two eyes of a single observer.

It was after I had conceived the idea, and constructed a double eye-piece, and had found it a very successful means of getting the personal equation, that I learned a similar contrivance had been used before. But my experiments upon it have been so successful, and the advantages of its use are so great, that I have thought them to be of sufficient interest for publication.

The principal advantage in its use consists in greatly diminishing computation for the reduction of the observations. By the usual method, with a reticule of fifteen threads, the first five only can be taken by the first observer, when he must give place to the second, who quickly gets into some posture and catches the last five. The thread intervals must be obtained by multiplying each of the *ten* equatorial intervals by secant of the star. These must be applied to the *ten* observations for only *five* results. By using the double eye-piece *fifteen* results are obtained from the same star passage over the same reticule of fifteen threads; the middle tally lost before being the best of the three in this case, while the only computing required is the simple subtraction of each of the fifteen signals by one observer from those of the other, respectively. Consequently the work of weeks is reduced to that of days, and also the results are believed to be much better, as it has already been found that the probable error of a single result is diminished about one-third. This is probably due in a great measure to the fact that the observers can retain their postures throughout the observation, and thereby evade the rapid transposition unavoidable in the use of the single eye-piece. In quite a series of observations taken by using the single eye-piece, for a personal equation which was found to be nearly zero, the person second in order, without reference to which, who necessarily took his position at the instrument hurriedly, I have noticed, obtained almost invariably the smallest time for the transit of the star, with the illuminated end of the axis in either position. This shows a quickened action of the mind and nerves, causing the signal to be made by the depression of the key earlier than it otherwise would have been. If this disturbance is not equal in the two individuals, the resulting personal equation must be in error.

The supposed sympathy of mind with mind has been urged against the use of the double eye-piece, from the fact that the heads of the observers are in such proximity while observing. But I have been unable to detect the existence of any such influence in more than 1700 results which I have assisted in reducing. The resulting personal equation differed but ·^{s}005 from that obtained by using the single eye-piece. Two good results by any eye-piece are liable to a greater discrepancy.

The observations referred to above were recorded by the electro-chronographic process. In doing so it was found necessary to use two writing pens, either upon two chronographs or one. If upon one chronograph, two pen-carriages should be provided for it. I believe the chronography of every observatory should be thus equipped, then the observations of two observers at two different instruments, as the transit and equatorial, could be recorded at once, the two observers operating independently, and the two pens making their breaks from the action of the same break-circuit. I used two pen-carriages upon the same chronograph, taking one pen-carriage from another chronograph. They were so arranged that one pen commenced at the middle of the sheet while the other commenced at the edge. The chronographs were of the make of Wm. Bond & Son, of Boston. Each pen was connected with a battery, and each circuit provided with a key at the instrument. Both lines were independent, except at the clock, where both join the same wire and the same break-circuit. It was found that the batteries should be nearly equal, and like poles connected at the clock, so that the currents pass in the same direction over the break-circuit, otherwise the two currents become one without passing the break-circuit. But observing this, no difficulty was experienced in securing the independent action of the two pens from the keys of the observers, and their harmonious action from the single break-circuit. The keys were so constructed as to operate without emitting any audible sound to disturb the observers.

The double eye-piece could be so constructed as to be easily transformed into a binocular one. For example, the binocular described in a late number of *Silliman's Journal*, could be furnished with two straight tubes to receive the rays direct from the dividing triangular prism. These eye-tubes would then be separated by 120° of arc.

The eye-piece which I constructed had two reflectors of speculum metal in place of the triangular prism, so arranged as to bend the rays at right angles and throw them in opposite directions. The reflectors are inferior to the prism. I found the aberration most nearly corrected when the two plane convex lenses between the reflectors and image to be viewed were both placed with their convex surfaces toward the reflectors. For these I used lenses of 1¼ inches focal length, and placed them about one inch apart, with the nearest about ⅜-inch from the reflectors. The eye-tubes or cross tube 7 inches in length, had at the extremities, Huygenian combinations of lenses of 1¼ and ¾-inches focal length. The magnifying power of the eye-piece is about twenty diameters. The field of view with this combination is not entirely uniform. It diminishes in brightness and clearness slightly from edge to edge in a direction perpendicular to the plane which divides the rays. This defect presents itself more strongely when the eye-piece is attached to a telescope, the aperture of the object-glass of which is small compared with its focal length, because the divergence of the rays from any point of the image is only equal to the convergence of the cone of rays transmitted through the object-glass, so that the rays from a point near the edge of the field do not spread sufficiently to allow an equal portion to fall upon the two reflectors. But examining an object separately with the eye-piece, this non-uniformity almost entirely disappears, because rays from any point of the object fall upon the entire surface of the objective, and become more generally diffused over the reflectors, and, consequently, more equally divided.

On the Invisible Radiation of the Electric Light. By John Tyndall, F. R. S.*

From the London Chemical News, No. 271.

Pending the preparation of my complete memoir, which may occupy me for some time to come, I would ask permission of the Royal Society to lay before the fellows a brief and partial summary of the results of my experiments on the invisible radiation of the electric light.

The distribution of heat in the spectrum of the electric light was examined by means of the linear thermo-electric pile, applied to the solar spectrum by Melloni, Franz, Müller, and others. The electric spectrum was formed by lenses and prisms of pure rock-salt, its width being equal to the length of the row of elements forming the pile. The latter, standing at right angles to the length of the spectrum, was caused to pass through its various colors in succession, and to search the spaces beyond the region of color in both directions.

As in the case of the solar spectrum, the heat was found to augment from the violet to the red, while the maximum heating effect was observed beyond the red, and at a distance from the red, in one direction, equal to that of the green of the spectrum in the other.

The augmentation of temperature beyond the red in the case of the electric light is sudden and enormous. Plotting from a datum line the thermal intensity of the various portions of the spectrum, the ordinates suddenly increase in length beyond the red, reach a maximum, and then fall somewhat more suddenly on the other side. When the ends of the ordinates are united, the curve beyond the red rises in a steep and massive peak, which quite dwarfs the luminous portion of the spectrum.

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* Abstract of paper read before the Royal Society.

The comparative height and steepness of this peak are much greater than those obtained by Professor Müller for the solar spectrum. Aqueous vapor acts powerfully upon the invisible rays, and, doubtless, the action of this substance in our atmosphere has toned down the eminence beyond the red in Professor Müller's diagram. A solar spectrum, produced beyond the limits of the atmosphere, would probably exhibit as steep a peak as that of the electric light.

In the experiments now to be referred to, the rays from the electric light were converged by a small concave mirror. The glass mirror silvered at the back, which usually accompanies the camera of Duboscq's electric lamp, was one of the first employed. It was brought so near the electric light as to cast an image of the coal-points five or six inches in advance of the light. A solution of iodine in bisulphide of carbon, contained in a rock-salt cell, was then placed in front of the lamp; the light was thereby cut off, but the focus of dark rays remained, and various effects of combustion and incandescence were obtained at the focus. A mirror four inches in diameter, and silvered in front, will enable an experimenter to obtain most, if not all, the results now to be mentioned. I also employ a mirror eight inches in diameter, and having a focal length of eight inches, with excellent effect.

It is not necessary to enclose the opaque solution in a rock-salt cell. The vessel intended for a solution of alum, which usually accompanies the lamp of Duboscq, and the sides of which are of glass, answers admirably. It is not, however, quite deep enough for the several tests to which I have subjected it, and, in crucial experiments, I employ a deeper vessel with rock-salt sides.

With the eight-inch mirror, just referred to, behind the electric light, the opaque solution in front, and the focus of invisible rays about six inches distant from the electric light, the following effects have been obtained:

1. Wood, painted black, when brought into the dark focus, emits copious volumes of smoke, and is soon kindled at the two spots on which the images of the two coal-points fall.
2. A piece of brown paper placed near the focus soon shows a burning surface, which spreads over a considerable space, the paper finally bursting into flame.
3. Black paper brought into the focus is immediately inflamed.
4. The wood of a hat-box, similarly placed, is rapidly burnt through, and usually bursts into flame.
5. The end of a cigar, placed at the dark focus, is instantly ignited.
6. Disks of charred paper placed in the focus are raised to brilliant incandescence, surfaces of considerable extent being brought to a vivid glow. Charcoal is also ignited.
7. A piece of charcoal, suspended in a receiver of oxygen, is ignited in the dark focus and caused to burn brilliantly, the rays after crossing the glass of the receiver being still sufficiently powerful to heat the coal up to incandescence.

8. A mixture of oxygen and hydrogen is exploded in the dark focus by the ignition of its envelope.

9. A piece of zinc foil, blackened on one side to diminish reflection, is pierced and inflamed. By gradually drawing the strip, once inflamed, across the focus, it may be kept blazing for a considerable length of time. This is a particularly beautiful experiment.

10. Magnesium wire, presented suitably to the focus, burns with its intensely luminous flame.

In all these cases the effect was due, in part, to chemical action; this, however, may be excluded.

11. A plate of any refractory metal, sufficiently thin, and with its reflective power suitably diminished, is raised to incandescence in the dark focus. Gold, silver, copper, aluminium, and platinum have been thus rendered incandescent.

12. Platenized platinum shows the effect best; in a thin leaf it may be rendered white-hot, and on it is depicted an incandescent image of the coal points. When the points are drawn apart, or caused to approach each other, their incandescent images conform to their motion.

The assemblage of phenomena here described, and others to be referred to in my completed memoirs, may, I think, be properly expressed by the term "calorescence." This word involves no hypothesis, and it harmonises well with the term fluorescence, now universally employed with reference to the more refrangible end of the spectrum.*

For the Journal of the Franklin Institute.

On the Dynamometer at the Royal Technological Institute, Stockholm.

By John W. Nystrom, Acting Chief Eng., U. S. N.

The proceedings of the stated monthly meeting of the Franklin Institute, in the April number of the *Journal*, contain a discussion on the dynamometer employed in the steam expansion experiments in New York. I have, on former occasions, noticed that this valuable instrument is very little known, that a description of the one at the Royal Technological Institute, Stockholm, will probably be read with interest. This dynamometer ought to be employed in every scientific institution, for we have yet no better means by which to imbue the student with the real substance of dynamics. Any student who has

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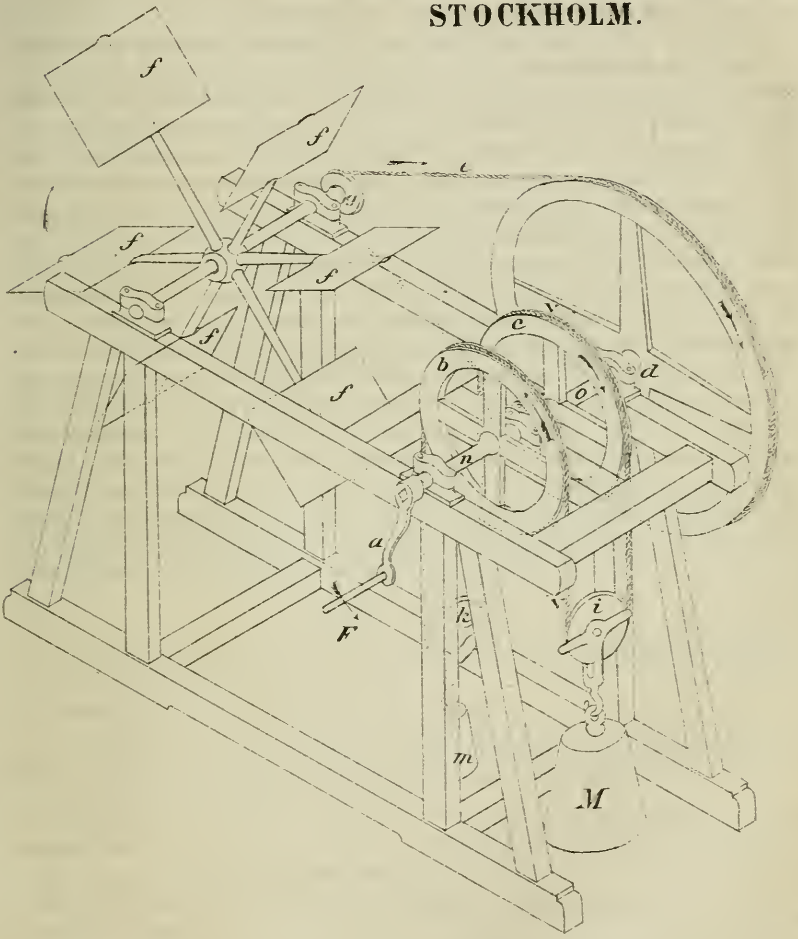
*On December 5, last, I tried the passage of the rays from the electric lamp through a great number of different colored glasses. Incandescence was obtained through almost all of them; and, in one instance, the radiation passing through a blue glass, the thermograph of the coal points was of a pink color. A thick, black glass, obtained from Mr. Ludd, when held in front of the lamp, was found to be not perfectly opaque, still, the platinum could not be raised to incandescence at all when placed in the focus. Being called away from the Royal Institution early in the afternoon, I gave directions to my assistant, Mr. Barret, to continue the experiments. He informs me that, on placing in the path of the rays a combination of two thin plates of black glass, one transmitting a whitish green, and the other a deep red, the light was entirely intercepted and feeble, though distinct incandescence was obtained at the focus. With radiation through the solution of iodine, the thermograph on this day rose to a white heat.

DYNAMOMETER
of the
Royal Tech: Institute
STOCKHOLM.



worked this instrument for a few hours, will probably not commit the error of saying that *work is independent of time, or that time* is included in power.

This dynamometer does not only teach the student the different properties of *force, power, and work*, but it enables him to conceive and compare, with great precision, real magnitudes of those quantities, which is of great importance in designing machinery.

The accompanying plate IV, represents an isometric perspective view of the dynamometer. The power is applied on the crank a, and communicated through the pulley b, rope V, pulley c, wheel d, rope e, rope-pulley g, and is consumed by the fans $f f f$. The shafts n and o are in one line, but not connected between the pulleys b and c. The endless rope V V is held tight in the grooves of the pulleys b and c by means of two weights m and M, as will be understood by the drawing. If the two weights were alike they could communicate no motion to the pulleys, but suppose $m = 10$ pounds, and $M = 20$ pounds, then there would be 10 pounds more weight on the sheave i, than on the sheave k, of which five pounds would pull on each pulley b and c. Let the radius of the crank a be equal to the radius of the pulleys, then it would require a force of five pounds to turn the crank in the direction of the arrow. If the crank is turned with an irregular velocity, it would only raise or lower the weights, but a constant force of five pounds would always act on the pulley c to communicate motion to the fans. The power in operation will be equal to the force multiplied by the velocity of the rope V, and the work accomplished will be equal to the power multiplied by the time of operation.

Notation of Letters.

R = radius of the crank in feet, which we have supposed to be equal to the radii of the pulleys b and c.

F = force in pounds acting on the crank a.

V = velocity in feet per second of the rope V, which, in the supposed case, will be equal to that of the velocity of the crank-pin.

t = time of operation in seconds.

P = power in dynamic effects, of which there are 550 per horse power.

W = work, in foot-pounds of work.

n = number of revolutions per minute of the pulley c.

Then we have

$$\text{the force } F = \tfrac{1}{2}(M - m), \text{ and velocity } V = \frac{2\pi R n}{60}.$$

$$\text{Power } P = F\,V, \text{ and work } W = F\,V\,t.$$

Example.—Radius of the crank or pulleys, $R = 1{\cdot}25$ feet, making $n = 28$ turns per minute. $M = 80$, and $m = 20$ pounds. Required, the force $F = ?$, velocity $V = ?$, power $P = ?$, and how much work, $W = ?$, will be accomplished in one hour, or $t = 3600$ seconds.

Force $F = \frac{1}{2}(80 - 20) = 30$ pounds.

$$\text{Velocity } v = \frac{2 \times 3{\cdot}14 \times 1{\cdot}25 \times 28}{60} = 3{\cdot}66 \text{ feet per second.}$$

Power $P = 30 \times 3{\cdot}66 = 109{\cdot}9$ effects.

Work $W = 109{\cdot}9 \times 3600 = 3956{\cdot}4$ foot-pounds.

The average power of a man working eight hours per day, is 55 effects, which will be an accomplished work of $W = 55 \times 8 \times 3600 = 1584000$ foot-pounds in a day's work.

In order to regulate the velocity to suit the power, the dynamometer has an arrangement by which to set the fans at any desired angle while in motion, which arrangement is not shown on the drawing. Students used to work the dynamometer in a spirit of emulation to outdo each other in power and work. Some could accomplish the greatest power, and work with less force and more velocity, whilst others preferred more force and less velocity.

Arrangements could easily be made to register on the dynamometer the force, velocity, power, and work, in the form of diagrams.

I do not know the origin or the inventor of this dynamometer, but, from the details of construction, would suppose it to be very old.

In the year 1850, I made a great many experiments with different screw propellers, when I employed a dynamometer of this description, made by Thomas Mason, of Philadelphia, which gave great satisfaction, and I have always considered it the best form of dynamometer where it can be conveniently applied. In regard to the mechanism for receiving the work in the New York expansion experiments, it appears to me that a paddle-wheel, or propeller, wholly immersed and revolving in water, would be better than the numerous fans working in air. Water would form a more substantial receiver of work, and, at the same time, would combine the interesting experiment of Mr. Joule, to regenerate and realize the work in the form of heat in the water.

For the Journal of the Franklin Institute.

Particulars of Iron Steamships.

Caledonia.—Hull built and machinery constructed by Messrs. Tod & McGregor, Glasgow, Scotland. Route of service, New York to Glasgow. Owners, Anchor Steamship Company.

Hull.—Length on deck, 261 feet 6 inches. Breadth of beam, 33 feet 2 inches. Depth of hold, 21 feet 6 inches. Depth to spar-deck, 28 feet 9 inches. Number of decks, 3. Draft at load-line, 19 feet. Frame of wrought iron plates, $\frac{7}{8}$ to $\frac{3}{4}$ of an inch in thickness, and fastened with rivets $\frac{3}{4}$-inch in diameter, and $2\frac{3}{4}$ inches apart. Floors, shape, Z L, molded, 5 inches, sided, $\frac{3}{8}$-inch, apart at centres, 18 inches. Beam ties on each deck. Bulkheads, 5. Rig, barque. Tonnage, 1393 tons, O. M.

Engines.—Vertical direct. Number of cylinders, 2. Diameter of cylinders, 42 inches. Length of stroke of piston, 3 feet.

Boilers.—Two, tubular. Have water bottoms.

Propeller.—Diameter, 14 feet. Number of blades, 2. Material, cast iron.

REMARKS.—A first-class vessel. Built and fitted as an ocean passenger steamship should be.

Atalanta.—Hull built and machinery constructed by Messrs. Smith & Rogers, Glasgow, Scotland. Route of service, New York to London. Owners, London and New York Steamship Company.

Hull.—Length on deck, 338 feet. Breadth of beam, 34 feet 6 inches. Depth of hold, 13 feet 9 inches. Depth to spar-deck, 22 feet 2 inches. Number of decks, 2. Draft at load-line, 21 feet. Frame of wrought iron plates, 1 inch to $\frac{3}{4}$ of an inch in thickness, and fastened with rivets $\frac{3}{4}$-inch in diameter, and 4 and $4\frac{1}{4}$ inches apart. Floors, shape, Z L, molded, 6 inches, sided, $\frac{5}{8}$-inch, apart at centres, 18 inches. Beam ties on each deck. Bulkheads, 6. Rig, four-masted barque. Tonnage, 1988 tons, O. M.

Engines.—Steeple. Number of cylinders, 2. Diameter of cylinders, 60 inches. Length of stroke of piston, 4 feet.

Boilers.—Two, tubular. Have water bottoms.

Propeller.—Diameter, 18 feet. Number of blades, 2. Material, cast iron.

Remarks.—A well built and well fitted vessel, complete in her equipment, and having large passenger accommodations and cargo-carrying capacity.

Washington.—Hull built by Messrs Scott & Co., Greenoch. Machinery constructed by Greenoch Foundry Company. Route of service, New York to Havre. Commander, Captain A. Duchesne. Owners, Compagnie General Transatlantique.

Hull.—Length on deck, 350 feet. Breadth of beam, 45 feet. Depth of hold, 22 feet 8 inches. Depth to spar-deck, 33 feet. Number of decks, 4. Draft at load-line, 17 feet 6 inches. Frame of wrought iron plates, 1 inch to $\frac{3}{4}$-inch in thickness, and fastened with rivets $\frac{7}{8}$-inch in diameter, and 3 inches apart. Floors, shape, Z Z, molded, $6\frac{1}{2}$ inches, sided, $\frac{3}{4}$-inch, apart at centres, 20 inches. Wrought iron plate stringers on two decks. Bulkheads, 6. Rig, brig. Tonnage, 3443 tons, O. M.

Engines.—Side lever. Number of cylinders, 2. Diameter of cylinders, $94\frac{1}{2}$ inches. Length of stroke of piston, 8 feet 8 inches. Nominal horse power, 850. The levers are of malleable iron, each 24 feet long, 7 feet wide at centre, $2\frac{1}{2}$ inches thick, and weighing 15 tons.

Boilers.—Four, tubular. Have water bottoms. Length of boilers, 22 feet. Breadth, 12 feet. Height, 14 feet. Number of tubes in each boiler, 284; brass. Weight of each, about 60 tons. These boilers are encased in malleable iron plates, 2 inches apart from the boilers, and so constructed that any portion can be removed without taking down the whole casing.

Water-wheels.—Diameter, 37 feet 6 inches. Material, iron.

Remarks.—This magnificent steamship deserves more than a passing notice. It is built in the most approved manner, and reflects great credit upon her builders, who are universally known and accepted as one of the most successful ship-building firms in Europe. This vessel has accommodations for three hundred and fifty first-class passengers, and capacity for 1000 tons of freight, besides being able to store 1500 tons of coal in her bunkers. Her interior is beautifully decorated and sumptuously fitted up. The steamships *Lafayette* and *Europe*, running upon the same route, are sister ships to the *Washington*, and were constructed by the same builders, whilst the *France* and *Napoleon III*, of similar dimensions, will soon be ready to take their respective positions in the line. The two last vessels are being constructed by Messrs. Scott & Co., at St. Nazaire, France.

Westminster.—Hull built and machinery constructed by Messrs. Fossick & Hackworth, England. Route of service, New York to Liverpool. Owners, National Steam Navigation Company.

Hull.—Length on deck, 271 feet. Breadth of beam, 38 feet. Depth of hold, 29 feet 9 inches. Number of decks, 3. Draft at load-line, 18 feet 6 inches. Frame of wrought iron plates, ⅞ to ¾-inch in thickness, and fastened with rivets ¾-inch in diameter, and 3 inches apart. Floors, shape, **Z L**, molded, 6 inches, sided, ⅝-inch, apart at centres, 18 inches. Beam ties on two decks. Bulkheads, 5. Rig, barque. Tonnage, 1897 tons, O. M.

Engines.—Vertical direct. Number of cylinders, 2. Diameter of cylinders, 60 inches. Length of stroke of piston, 2 feet 9 inches.

Boilers.—Four, tubular. Have water bottoms.

Propeller.—Diameter, 16 feet. Number of blades, 3. Material, cast iron.

REMARKS.—A first-class, superior built steamship, having great strength, comfort, and safety combined in her construction. She is fitted with all that is requisite in a vessel of her character, and that this is appreciated is evident from the hundreds of passengers she regularly lands in New York.

*Iowa.**—Hull built by Messrs. Malcomson Bros., Waterford. Machinery constructed by Messrs. Smith & Rogers, Glasgow. Route of service, New York to London. Owners, London and New York Steamship Company.

Hull.—Length on deck, 338 feet. Breadth of beam, 34 feet 6 inches. Depth of hold, 13 feet 9 inches. Depth to spar-deck, 22 feet 2 inches. Number of decks, 2. Draft at load-line, 21 feet. Frame of wrought iron plates, 1 inch to ¾-inch thick, and fastened with rivets ¾-inch in diameter, and 4 and 4¼ inches apart. Floors, shape, **Z L**, molded 6 inches, sided, ⅝-inch, apart at centres, 18 inches. Beam ties on each deck. Bulkheads, 6. Rig, four-masted barque. Tonnage, 1988 tons, O. M.

Engines.—Steeple. Number of cylinders, 2. Diameter of cylinders, 60 inches. Length of stroke of piston, 4 feet.

Boilers.—Two, tubular. Have water bottoms.

Propeller.—Diameter, 18 feet. Number of blades, 2. Material, cast iron.

REMARKS.—This vessel is well fitted, and is a first-class steamship.

City of Boston.—Hull built and machinery constructed by Messrs. Tod & McGregor, Glasgow, Scotland. Route of service, New York to Liverpool. Commander, Captain James Kennedy. Owners, Philadelphia, New York and Liverpool Steamship Company.

Hull.—Length on deck, 305 feet. Breadth of beam, 39 feet. Depth of hold, 27 feet 6 inches. Number of decks, 3. Draft of water, 20 feet. Frame of wrought iron plates, 1 inch to ¾-inch thick, and fastened with rivets 1 inch and 1¼ inches in diameter, and 2½ and 3 inches apart. Floors, Shape, **Z Z**, molded, 6 inches sided, ½-inch, apart at centres, 21 inches. Beam ties on all decks. Bulkheads, 5. Rig, ship. Tonnage, 2254 tons, O. M.

Engines.—Trunk. Number of Cylinders, 2. Diameter of cylinders, 69 inches. Length of stroke of piston, 3 feet.

Boilers.—Four, tubular. Have water bottoms.

Propeller.—Diameter, 18 feet. Number of blades 3. Pitch, 24 feet. Material cast iron.

REMARKS.—For strength, speed, and beauty, this vessel cannot be excelled. She is constructed in the very best manner, and will, undoubtedly, sustain the high fame of the line for which she was built. The deck is made of iron plates of the best quality, manufactured by the Mersey Steel and Iron Company, and upon these plates is laid the ordinary timber deck. This line now consists of thirteen of the finest screw steamships afloat, and there are two more, the *City of Paris* and the *City of Durham*, now being built. Originally the line consisted of one or two ships only, and its rapid rise may be attributed to the tact and talent of its officers. The company have achieved a great success, and they deserve it, because they have worked for it.

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* This vessel recently ran upon a rock near Cherbourg, and was sunk.

E. M. B.

For the Journal of the Franklin Institute.

Speed of Ships

The clipper ship *Sea Serpent*, Captain Winsor, arrived at San Francisco on the 16th of March, 1865, having made the run from New York in 102 days, which is the second shortest passage made during the past four years. Within the above period, the best runs have been those of the *Panama* in 100 days, the *David Crockett* in 107 days, and the *Sea Serpent* in 102 days, all of them belonging to Messrs. Sutton & Co.'s line, New York.

The Panama Railroad Company's barque *Xantho*, Captain Conway, left New York March 3d, 1865, arrived at Aspinwall in 12 days, left there March 24th, arriving at New York April 5th, in 12 days, making the voyage in 33 days, being the shortest on record.

The barque *Albertina*, Captain Richard Olmstead, formerly in the Havana trade, has made the voyage from Port Elizabeth, Algoa Bay, to New York in the remarkable time of 45 days.

The barque *Imaum*, of Boston, Captain Luther Hurd, has made the voyage from Boston to Marseilles, thence to Messina, discharging and taking in full cargo at each port, and returning to Boston in 100 days.

E. M. B.

The Value of Stone Under Fire.

From the London Builder, No. 1156.

The superintendent of the London Fire-engine Establishment, in his last report, to which we have already alluded, comments on the errors and omissions of the Building Act. In the course of these observations he quotes:

"Sec. 22. The lobbies, stairs, &c., of a certain class of buildings must be made of 'stone or other fire-proof material;'" and says: "This enactment involves an error, inasmuch as stone is in no sense fire-proof; on the contrary, it yields to fire sooner than almost any other building material, and much more rapidly than wood. It is true that it does not, like wood, add fuel to the fire, but it does worse, as its known tendency to split off from the walls, and fall down altogether, prevents the firemen from availing themselves of the best positions for their work, which they can almost always occupy where there are wooden staircases. For a staircase on the outside of a building, stone may be safely used, but its brittleness, when exposed to different degrees of heat in different parts, makes it an unsafe material for inside staircases or lobbies, which are liable in case of fire to undergo a sudden expansion in the tread or exposed part, while the support or part resting inside the wall is scarcely raised in temperature; or, if they escape this danger, and get hot so slowly as not to break, the water from the engines, or even in some cases the draught of cold air caused by opening a door or window, is quite sufficient to contract and split the stone. In both cases the fracture occurs in the same place, close to the wall."

The reporter then goes on to say: "No staircase can be really fireproof, unless constructed either of fire bricks laid in fire cement, which would be both costly and cumbrous, or of wrought iron, which for appearance, comfort, or convenience, might be covered with slabs of slate, stone, or wood. In this latter case the real strength would consist, not in the stone or other covering, but in the wrought iron framing; and such stairs, particularly if protected by plaster, which could be easily done, might safely be relied on in all ordinary fires, as the heat near a staircase being tempered with the cold draught from the outside is rarely sufficient to weaken wrought iron, which only fuses at about 3000° Fahrenheit, and retains a considerable portion of its strength almost to the melting point. That paragraph which asserts that stone is a fire-proof material suited for lobbies, stairs, &c., has done incalculable injury, as may be observed at the scene of any fire in a building so constructed, particularly if there have been both wooden and stone stairs, in which case it almost invariably happens that some part of the wooden stairs is saved, while the stone is completely destroyed, and generally discovered afterwards among the ruins in the basement. It seems, therefore, wrong to continue any longer a compulsory law based on a grave error, and certain always to do, as it has already done, most serious injury to life and property. The only way in which a stone staircase can be saved in a building on fire, is to flood it with water at an early stage, and this must always occupy the attention of the firemen at the very time when their efforts would otherwise be exerted in a totally different direction."

Of course the experience of the superintendent in this direction has been considerable, but we should be glad, nevertheless, to have some additional evidence as to the behavior of all stone staircases under fire.

The Hydrostatic Girder.

From the London Mechanics' Magazine, April, 1865.

The hydrostatic girder is the name applied to a new invention, by the use of which the pressure resulting from any weight which it may be found necessary to place upon a girder, is equally distributed over the whole surface. This distribution of pressure tells best in a large bridge or viaduct, as by its application in such cases the whole of the structure may be made of lighter material, at a consequently reduced cost, without any diminution of safety. The girder consists essentially of two hollow girders, one of which just fits into the other, allowing a small space around it to be filled with water. The weight which the whole girder is required to support is placed upon the smaller or floating girder. In ordinary girder bridges the weight of a passing train has to be borne by every inch of the girder in succession ; and when the supports are far between this necessitates a great increase in the strength of the structure, with its consequent increase of expenditure.

The principal advantages in the hydrostatic girder arise from making the floating girder continuous, or without any other support than the water between it and the larger girder throughout the whole length. From well-known hydrostatic laws it is evident that, wherever the weight may be placed upon the floating girder, (which weight must, of course, be proportional to the amount of water displaced by the floating girder,) the pressure arising from such weight will be distributed over the whole of the lower girder. Another advantage of the new construction is the absence of that vibration caused by the passage of a heavy train which is so injurious to cast iron structures. It may be observed that the principle of the hydrostatic girder is not limited to bridge building. It is well known that the repairs to the permanent way, which form so large an item in railway expenses, are rendered principally necessary by the transit of those heavily-laden springless trucks of coal, which operate upon every inequality of the line in their passage, with all the injurious effects of a steam hammer. By a simple application of the hydrostatic principle a cheap and yet efficacious spring might be provided, obviating in a great measure the damages caused to the permanent way.—*Building News.*

Steel Locomotives.

From the London Mechanics' Magazine, April, 1865.

The Maryport and Carlisle Company have for some time past employed steel to a great extent in substitution for ordinary iron for the working parts of locomotives, and, as we are informed, with the most satisfactory results. The traffic on the line is principally coal and mineral. It has been found that with the ordinary iron tires on the engine wheels, the distance run was not more than 90,000 miles—in many cases not more than 60,000 miles—and the wheels require to be taken from under the engine for every 20,000 or 30,000 miles run, for repairs and "turning up." In the case of the steel tires, however, the wheels will run 100,000 miles before they require "turning up" or repairing. The *Railway News* states that the result of a very careful examination of the effects of wear leads to the opinion that these wheels will run from 350,000 to 500,000 miles, or equal to some twelve or fifteen years work of a daily average of about one hundred miles. The difference of cost as between the two metals is not great; in the one case it ranges from £40 to £45 per ton, while the steel is about £55, the cost of labor in placing the tires on the wheels being nearly the same in each case. The company have a number of boilers, axles, cranks, and eccentrics, made of steel, in constant use on the line, and they have given the greatest satisfaction. These have not, however, been sufficiently long in operation to enable a comparison to be drawn between them and the ordinary portions of the locomotives; but there is reason to believe that the saving in point of wear will be equal to that effected by the substitution of steel for ordinary iron tires. The ordinary eccentrics are expensive to keep up, but those which are made of hardened steel do not require any looking after for ten years, not even to the slacking of a bolt, so far as regards repairs. The experience obtained on this, and we believe upon some other railways, points to a very important mode of saving in one of the largest items of cost in the working expense of railways. The subject will, we have no doubt, receive careful consideration from the managers of railways.

Singular Boiler Explosion.

From the London Mechanics' Magazine, April, 1865.

In the last report of Mr. L. E. Fletcher, Chief Engineer of the Manchester Boiler Association, an account is given of an explosion which occurred at an iron works, on the 9th February last, to a boiler which was not under the inspection of the Association. This explosion was of a very peculiar character, inasmuch as a plate, having a superficial area of about five square feet, was torn out of the side of the boiler through the solid metal, and shot away by the force of the steam, while the boiler remained in its place unmoved, and in other respects intact. By the flight of this piece of plate, as well as by that of a portion of the brickwork by which the boiler was surrounded, the roofing of part of the works was carried away, and two men were seriously injured. A few days after the explosion Mr. Fletcher visited the works, but found that repairs to the boiler had been commenced, and rent plates cut out, so that he had not so favorable an opportunity of conducting his investigations as could be desired. An engineer, however, who was previously familiar with the boiler and all its working conditions, and who examined it immediately after the explosion occurred, furnished full particulars and sketches. The boiler was one of six, which, though situated at different parts of the works, were yet connected together, both by the steam and feed-pipes. It was of the externally-fired upright furnace class, so commonly employed at iron works, and was constructed to receive the waste heat from three puddling furnaces. One of these had, however, been exchanged for a fire-grate of large dimensions, so that the boiler was heated by the flames passing off from two puddling furnaces and from one fire-grate. The height of the boiler was 24 feet, while its diameter was 7 feet 9 inches in the external shell, 4 feet in the central descending flue, and 2 feet in the three internal branch-tubes which radiated from it, the plates being $\frac{7}{16}$-inch in thickness, and the usual working pressure of steam about 35 lbs. per square inch.

The shape of the piece of plate blown out of the side of the boiler was an irregular parallelogram, measuring about 3 feet 6 inches vertically, and 1 foot 10 inches horizontally, at the widest part. It was intersected about mid-height horizontally by a ring seam of rivet, which encircled the boiler, and at this line the ejected plate tore asunder into two pieces of somewhat equal size, while the other rents round its circumference were through the solid metal. The hole made in the side of the boiler was situated, as nearly as may be, on a level with the inlets to the central descending flue, and a little to the right hand to the one fed from the fire-grate, which had been substituted for the puddling furnace, so that it will be seen that the rupture took place near to, but somewhat below, low water mark. The cause of this remarkable rent did not appear to have been brittleness of the plates, since they withstood repeated and severe blows with a heavy hammer, neither does the local character of the injury allow of its being attributed to overpressure of steam, but there seems little reason to doubt that the rent was caused by the plates being overheated, since it appeared upon examination that the sides of the boiler had bulged four inches outward, in the first place, and then rent down the centre of this bulge in a vertical direction, folding back on one side very much like the leaf of a book, or a door on its hinges, the edges of the plates at the primary rent—which was shown to be such by the direction of the flight of the parts—being drawn out, as they only could have been when the metal was hot, while the fracture at the hinge was that of colder metal. This overheating has been attributed to shortness of water, but the man in attendance stated that the float indicated an ample supply—there being a depth of 3 feet 6 inches over the crown of the central descending flue-tube—and that the feed was not only going into the boiler when the explosion occurred, but had being doing so for some time previously; while it may be added that there was a feed back-pressure valve fixed to the boiler to prevent the water from returning through the feed-pipe, and that the float is reported to have been in working order.

Shortness of water is by no means essential to the overheating of the plates in a boiler when they are played upon by an intense fire, and the flames allowed to impinge locally, especially if the water be not good; and many cases have been met with in which, under these circumstances, plates have become overheated, although there has been plenty of water in the boiler at the time. In the present instance, the flames from the large fire-grate—which was fed with coal instead of slack, in order to raise more steam—played directly upon the vertical side of the boiler, and just at the part where the rupture occurred, while the water contained a good deal of loose sludgy deposit, and was found frequently to foam up, and cause the boiler to prime. In vertical heating surfaces, the steam is apt to cling to the plates, and to creep between them and the water. This, in the upright single flue internally-fired furnace boiler, in frequent use at iron works, has been found to have such an injurious effect upon the flue-tube, and lead to so many collapses, that this description of boiler has in many cases been discarded. There is, therefore, every probability that the overheating was due, not to a deficiency in the supply of the water, but to its being driven away from the plates by the rapid ebullition of steam within the boiler, caused by furious firing, and the too local impingement of the flames upon a vertical surface combined with the use of sludgy water. This view is corroborated by the fact, that when overheating occurs in consequence of ordinary shortness of water, the plates are injured in a line parallel to its surface, whereas in this case they both bulged and rent in a line at right angles to it, and for a length of as much as 3 feet 6 inches. So that the statement of the fireman may after all be correct, that there was plenty of water in the boiler at the time of the explosion, while its occurrence is only another illustration of the dangerous character of these externally-fired upright furnace boilers.

The Injurious Action of Alkalies on Cotton Fibre. By Messrs. Heinrich Caro and William Dancer.

From Newton's London Journal of Arts, May, 1865.

A remarkable instance of the deleterious action of alkali on cotton fibre lately came under our notice, when examining some indigo prints which had been stiffened or finished with silicate of soda, and kept in bales during about two years. The strength of the fibre of the greater part of these goods had decreased to about one-third of the strength of some pieces which had been packed in the same bales, and which differed in no other respect from the others, except in their having been finished with starch. We therefore surmised that silicate of soda had been the primary cause of the deterioration of the goods. Further observations convinced us, however, that the injury was due to the long continued action of free or carbonated alkali upon the cotton fibre.

Some of the sound pieces (which, as before mentioned, had been finished with starch), had been packed between the silicated goods, and had abstracted soda from them which had penetrated from the places of contact into the interior of the pieces to a considerable depth. In the same ratio in which the pieces had taken up soda, it was found that they had diminished in strength. On the other hand, it was found that in such places of contact, the silicate of soda of the silicated goods had suffered a partial decomposition, extending to the depth of four or five layers of the pieces. The silicate of soda in the middle of the pieces contained from 70 to 74 per cent. of silicic acid, combined with from 30 to 26 per cent. of soda; whilst the analysis of the silicate of soda contained in the contact layers, showed that from one-third to two-thirds of its soda had been extracted. This loss of soda was accompanied by a change of strength of the cloth which appeared to bear some proportion to it, the layers or folds of the cloth *decreasing* in strength as they were removed from contact with the starched goods, until the silicate of soda attained the same composition as that found in the most rotten parts of the piece, this generally taking place about the fourth or fifth layer or fold of the piece, as before stated.

The following table shows the change in strength produced by this decomposition of the silicate of soda :

Finished with Starch.			Finished with Silicate of Soda.					
	Middle.	Contact Layer.	Contact Layer.	2d.	3d.	4th.	5th.	Middle.
Strength.	100	81	89	68	62	54	48	35

The silicate of soda had evidently been decomposed with the formation of free alkali and an acid silicate, which appears to have very little action on the cotton fibre.

In some places the decomposition had gone further, and free silicic acid had separated out in the form of a white powder upon the surface of the cloth. The same decomposition, accompanied by the same changes in the strength of the cloth, was observed upon all pieces which had been in contact with the paper used for wrapping the bales. In this instance the paper had absorbed the liberated soda, and the cloth in contact with it had almost entirely retained its original strength.

The white portions of the patterns were in a further advanced state of decay than the blue ones, in most instances retaining only 10 per cent. of their original strength. In the goods finished with starch only, the whites were equally as strong as the blues. In the goods finished with silicate of soda, the whites were almost as strong as the blues in all places where the before-mentioned decomposition of the silicate of soda had been accompanied by an abstraction of soda ; but in the interior of the goods, where the silicate of soda had retained its original composition, the strength of the whites had decreased to about one-third of that of the blues. It was therefore evident that this excessive decay of the whites was due to some cause which had assisted the action of the alkali upon them ; and we believe to have found an explanation of this in the action of the silicate of soda upon the sulphate of lead contained in them to the amount of about 10 per cent. of the mineral ash.

Sulphate of lead has been an ingredient of the resist paste printed upon the places intended to remain white, and by the subsequent action of lime and sulphuric acid it has become fixed in the fibre. We have noticed that sulphate of lead decomposes solutions of silicate of soda very rapidly, with formation of sulphate of soda, free silicic acid, and silicate of lead.

These changes give rise to the production of a crystallizable and strongly efflorescent salt, and to increase in bulk; and we think that the mechanical effect produced by the crystallization of the sulphate of soda formed may have caused a further and final integration of the fibre already weakened by the action of the alkali. Under the microscope the fibre of the white portions of the pattern presented the appearance of *cylindrical* tubes, partially covered with minute crystals (soluble in water); in some places these tubes appeared to be split longitudinally.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By George F. Rodwell, F.C.S.

From the London Chemical News, No. 269.

Continued from page 340.

10. *Robert Hooke.*—Robert Hooke was born in 1635. In 1653 he went to Oxford, where he made the acquaintance of Boyle, who was so struck with his aptitude for devising experiments and constructing apparatus that he engaged him as his assistant; and these two greatest experimental philosophers of the age immediately succeeding that of Bacon worked together for several years on numerous branches of science. Hooke was a man of great erudition—his writings relate to all the physical sciences known at the period; he excelled greatly as a mechanician, and his inventions are said to number more than a hundred. Among others we may mention the circular pendulum, the wheel barometer, and instruments to graduate thermometers, to measure time with exactness, to determine the refractive power of liquids, to grind optical glasses, and to show the number of vibrations of a string requisite to produce a certain note. Moreover, he greatly improved the microscope and telescope.

Hooke's first scientific treatise* was published in 1661; in it he endeavored to explain the cause of some effects observed by Boyle, as to the rise of water in tubes of small diameter. It was the ingenuity of this treatise which first brought Hooke before the notice of the recently formed Royal Society, and it was immediately proposed that he should be requested to act as curator to the Society. To this office he was elected on November 12, 1662, and it was ordered that he should be required to show "three or four considerable experiments" whenever the Society met; a vote of thanks was passed to Boyle for dispensing with the services of so valuable an assistant.

At the following meeting, (November 19,) Hooke showed some experiments to prove the weight of air. A globe of glass, the interior of which communicated with the air by a tube of small diameter, was heated to bright rednesss, and sealed before the blow-pipe; when cool it was placed in the scale of a balance, and counterpoised by weights of the opposite scale; on now breaking off the end of the tube so as to admit air to the globe, the latter preponderated. Into a similar globe a small quantity of water was introduced, which was completely evaporated, the globe heated to redness, sealed before the blow-pipe, and counterpoised as in the previous experiment; on admitting air the globe preponderated, and the weight of air which had entered was shown by placing weights on the opposite scale, until equilibrium was restored. On December 3 he varied the experiment: two small glass globes, one and a half inch in diameter, were sealed at the ordinary temperature, and suspended from one end of the beam of a balance in such a way that the globes preponderated; the balance was introduced into an air-tight vessel into which air was condensed, the globe now ceased to preponderate; on allowing the condensed air to escape from the vessel, the globes returned to their former position.

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* This treatise extends over fifty small pages. It is entitled "An attempt for the explication of the phenomena observable in an experiment published by the Hon. Robert Boyle, in the 35th experiment of his epistolical discourse touching the air. In conformation of a former conjecture made by R. H." London: 1661. Hooke re-published this treatise four years later in the "Micrographia." (Obs. 6, "Of small glass canes.")

In 1664 Hooke presented the manuscript of his "Micrographia"* to the Royal Society, and the President, by an order dated November 23, 1664, ordered it immediately to be printed. The "Micrographia" is chiefly devoted to the description of microscopic bodies, but it also contains a great amount of experimental observation in various branches of natural philosophy, particularly in optics; it is in every way worthy to be among the first works published by a Society instituted for the purpose of investigating natural phenomena by experiment.

In the preface, Hooke describes the wheel barometer which he had recently devised for showing minute changes in the pressure of the air; the circle was divided into 200 parts, but there were no indications upon it to show what kind of weather might be expected when the index stood at a certain point. From a number of observations, Hooke found that the mercury invariably fell before rainy weather, and that it rose before dry weather and during the prevalence of an easterly wind.

The air, according to Hooke, is a mixture of terrestrial and aqueous particles, "dissolved and agitated by the ether;" and just in the same way that a few grains of salt may be diffused through a large quantity of water, so, he says, a small quantity of water may expand and diffuse itself through a large space; on the other hand, as a small quantity of water is able to dissolve a quantity of salt which could diffuse itself through a large quantity of water, so a quantity of air which could expand and diffuse itself through a large space may be contained within a small compass.

In the 7th observation of the "Micrographia," Hooke describes the spirit thermometer which he introduced into England, and which had been invented a few years previously by one of the members of the Accademia del Cimento. Hooke constructed thermometers of such delicacy that, although the stem was four feet long, the spirit rose nearly to the top of the tube in summer, and sunk nearly to the bulb in winter. The freezing point of water was the zero of the scale.

Observation 9 is entitled, "Of the fiery sparks struck off from a flint or steel." It was anciently believed that, when flint and steel are struck together, sparks are produced by the attrition of the air. Lucretius supposed that lightening is produced by the collision of two clouds, in the same way that sparks are produced by the collision of flint and steel. Bacon† mentions that the sparks descend, and when extinguished are found to be a kind of "dark ash." He affirms, moreover, that they are in reality particles struck off from the flint or steel, raised to ignition by the violence of the friction. Des Cartes endeavored to explain the production of the sparks according to his three-element theory,* and in so doing gave a most obscure and unphilosophical explanation; this induced Hooke to examine the phenomenon for himself. Accordingly he collected a number of the particles which had appeared as sparks of fire when first struck off from the steel, and examined them under the microscope; they were then seen to be spheres with a metallic lustre so bright that bodies could be seen reflected in them. The sparks are, therefore, he contends, minute particles of steel which, by the violence of the friction, are raised to a red heat, and then take fire and burn, because "there seems to be a very combustible sulphureous body in iron or steel, which the air very readily preys upon, as soon as the body is a little violently heated."

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* "Micrographia, or some Physiological Descriptions of Minute Bodies made by Magnifying Glasses." London: 1665.

† "Novum Organum," Book 2, Aph. 12.

To be Continued.

New Electro-magnet.

M. Du Moncel presented to the French Academy of Sciences at their meetings on the 9th and 16th of January last, the results of his examination into a very curious and useful discovery made by M. Carlier, a machinist of Paris. Heretofore in constructing an electro-magnet it has been considered indispensable to devote the greatest attention to the insulation of the different turns of the wire from each other by wrapping with silk or cotton, or carefully varnishing. It occurred to M. Carlier to try the effect of wrapping with a simple uncovered wire, and, greatly to the astonishment of electricians, it is found that under certain conditions, the attractive force of the magnet is greatly increased, while its extra or inductive current becomes scarcely sensible. Thus an electro-magnet, having an iron core 4½ centimetres long and 7 millimetres in diameter, carrying a single row of spires of fine wire 0·277 mm. diameter, in all 103 spires, supported under the influence of two small Bunsen couples, 3·9 kil., while the same core wrapped with a covered wire, supported only 2·4 kil. It is true that but 77 turns of the covered line could be put upon the core. The effects at a distance was still more favorable to the uncovered wire.

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* The basis of the physical philosophy of Des Cartes is the hypothesis that all matter consisted originally of square particles, which at the creation were endowed with two motions—the one causing each particle to revolve separately, the other causing groups of particles to revolve around a common centre. The particles during their revolution gradually had their angles worn down by the frequent friction, and thus three elements were produced. The first element, of which the sun, stars, and fire are composed, is the dust produced by the abrasion of the angles; the second, which constitutes the atmosphere, and all the matter between the earth and the stars, consists of the spheres which remain when the angles of the original square particles have been worn perfectly smooth; and the third, of which the earth and all terrestrial bodies are composed, consists of the particles which are neither spherical nor square, but which are partly worn smooth and partly have their angles remaining.

The following is the explanation which Des Cartes gives of the production of sparks by the collision of flint and steel:—" . . . consideremus primo varios modos quibus ignis generatur. . . . Nihil usitatius est, quam ut ex silicibus ignis excutiatur; hoc que ex eo fieri existimo, quod silices sint satis duri et rigidi, simulque satis friabiles, ex hoc enim quod sint duri et rigidi, si percutiantur ab aliquo corpore etiam duro, spatia quæ multus eorum particulas interjacent, et a globulis secundi elementi solent occupari, solito fiunt angustiora, et ideo isti globuli exsilire coacti, nihil præter solam materiam primi elementi circa illas relinquunt deinde ex eo quod sint friabiles, simul ac istæ silicum particulæ non amplius ictu premuntur, ab invicem dissiliunt, sicque matariæ primi elementi, quæ sola circa ipsas reperitur, innatantes ignem componunt."—"Principia," Pars quarta, par 84.

It is to be observed that if more than one thickness of wire coil is put over the core, the different thicknesses must be carefully insulated from each other by paper. The wire, too, must be insulated from the core by paper, silk, or wood.

After a very careful study of the phenomena, showing that in order to produce these effects, the uncovered wire must be acted on by a battery arranged collaterally, or for quantity, and that with a battery arranged consecutively, (or for intensity,) the covered wire resumes its superiority, M. Du Moncel suggests that the phenomena depend upon a great number of minute currents, which are drawn from the main current at the points of contact of the turns of the wire, the main current following the wire, however, because in that direction the resistance is much the least. For this same reason these minute currents move around the wire instead of across it, and thus add considerably to the influence on the core, while they entirely prevent the induction effect by which is produced the annoying spark and counter-current at making and breaking connexion. He finishes his essay as follows:

"It results from all these experiments that quantity currents are particularly suited to electro-magnets with uncovered wire, and that their best effects are shown when the insulation of the bobbins is not too great and when the surface of the battery is in proportion to the number of turns of the wire.

Hydraulic Cements.

It has been for a long time a matter of reproach to practical science, that notwithstanding the great importance of the subject of cements, and the number of theoretical and experimental researches upon the subject by eminent engineers, we were still left to the most vague hypotheses upon the subject, and no competent chemist appears to have interested himself in the matter. M. Fremy has done away with this reproach, as far as he is concerned, in a memoir presented to the French Academy of Sciences, a digest of which is published in their proceedings of the 15th of May. Vicat assumed the formation of a double silicate of alumina and lime, which, by absorbing water, was the cause of the setting of the hydraulic cements, and this view seemed to be confirmed by finding in the calcined cements a silicate which formed a gelatinous precipitate with an acid, which silicate did not pre-exist in the stone before calcination.

MM. Rivot and Chatonay in an important investigation of cements, to which M. Fremy gives the highest praise, suggested that the calcination of the argillaceous limestone gave rise to an aluminate of lime having the formula Al_20_33Ca0, and to a silicate of lime represented by $Si0_33Ca0$, which salts brought into contact with water form hydrates each with six equivalents of water, and thus cause the settling.

The result of the experiments of M. Fremy is that the settling of cements is due to two different chemical actions: First, to the hydration of the aluminates of lime; and, secondly, to a puzzuolanic action, in which the hydrates of lime combine with the silicates of lime and alumina.

In the course of his experiments, M. Fremy found that alumina is even a better flux for lime than silica, and he suggests that the very basic compounds of these two substances, those, for instance, containing from 80 to 90 per cent. of lime may be useful in the iron furnace, owing to their disposition to absorb sulphur and phosphorus, and thus free the metal from these noxious impurities.

He also finds that no substance is capable of acting as a puzzuolana except the simple or double silicates of lime containing only from 30 to 40 per cent. of silica, and sufficiently basic to form a gelatinous precipitate with acid.

The Functions of Leaves of Plants.

The Proceedings of the French Academy of Sciences contain a communication from M. Boussingault on the subject of the functions of the leaves of plants, which will be of much interest to physiologists. The following is the summary of the results of his experiments:

1. Leaves exposed to the sun-light do not decompose pure carbonic acid, or, if they do, do it with extreme slowness.
2. Under the same circumstances in a mixture of carbonic acid and atmospheric air, they decompose the acid rapidly. The atmospheric air appears to have no active part in this phenomenon.
3. Leaves exposed to the sun rapidly decompose carbonic acid when mixed either with nitrogen or with hydrogen.

Although the decomposition of the acid is a phenomenon of dissociation, M. Boussingault traces a pretty close analogy between it and the slow combustion of phosphorus.

New Electric Battery.

M. Du Chemin, who, in a preceding communication to the Academy of Sciences of Paris, had announced that he had succeeded in replacing Nitric acid in the Bunsen battery by Perchloride of Iron, and the Sulphuric acid by Chloride of Sodium, writes to announce that by substituting for the latter salt the impure Chloride of Potassium of commerce, he has succeeded in increasing the motive and electric force, and that in this way the electric light may easily be obtained.

On Ancient Mortars. By WILLIAM WALLACE, Ph.D., F.R.S.E., F.C.S.

From the London Chemical News, No. 281.

Having, by the kindness of William Clarke, Esq., C.E., who has recently returned from the East, been supplied with specimens of mortars and plasters from well-known ancient buildings in Egypt, Greece, Italy, and the Island of Cyprus, I have submitted a number of them to analysis, with the object of determining several points of interest. The ages of the mortars vary from about 1600 to upwards of 3000 years, thus dating back to the most ancient historical periods. I propose in the present notice to give the results of the analysis of such of the specimens as I have examined.

Mortar of the Great Pyramid.—Two specimens of mortar from the Pyramid of Cheops were examined, one being from the interior, and the other from the outside of the structure. That from the interior was from the great chamber or the passage leading to it. Both specimens present the same appearance—that of a mixture of plaster of a slight pinkish color, with crystalized selenite or gypsum. They do not appear to contain any sand, the silicic acid being evidently in combination with alumina as clay. Part of the selenite was probably burnt, and the result mixed up with burnt lime, ground chalk, or marl, and coarsely-ground selenite. The latter would act the part of sand in our mortars, *i.e.*, prevent undue contraction in drying. The quantity of water is almost exactly what is required to form the ordinary hydrate of sulphate of lime with two equivalents of water. The mortar is easily reduced to fragments, but possesses a moderate degree of tenacity. Prof. C. Piazzi Smyth, who is at present making explorations in the pyramid, and to whom I have communicated the results of my analysis, has informed me that large quantities of gypsum and alabaster are found in its vicinity; and that some enormous slabs of alabaster or selenite have been discovered lining the walls of a large tomb recently opened. The material of which the pyramid itself is constructed being limestone, there is no difficulty in accounting for the presence of the lime.

	Interior.	Exterior.
Sulphate of lime, hydrated, . .	81·50*	82·89*
Carbonate of lime (CO_2 calculated), .	9·47	9·80
Carbonate of Magnesia (do.), .	·59	·79
Oxide of iron, . . .	·25	·21
Alumina, . . .	2·41	3·00
Silicic acid, . . .	5·30	4·30
	99·52	100·99

Ancient Phœnician Mortars from Cyprus.—Two specimens were obtained from Cyprus. The first is from the ruins of a temple near Larnaca, the highest stone of which at present remaining is five feet below the level of the ground, and the lowest about eighteen feet. Mr. Clarke supposes this to be the most ancient mortar in existence, and it certainly is one of the best I have ever seen. It is exceedingly hard and firm, and appears to have been made of a mixture of burnt lime, sharp sand, and gravel, some of the fragments being about half an inch diameter. On solution in hydrochloric acid, it gave a small quantity of soluble silica, amounting to ·52 per cent.

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* Water by actual estimation, 16·66, 17·38.

The other specimen from Cyprus is a cement used for joining water pipes. These pipes were found near Larnaca, ten feet below the surface of the ground, and bear evidence of extreme antiquity; they are of red clay, about eleven inches in diameter, and are connected by spigot and fawcet joints, the intervening spaces being filled with the cement, and afterwards coated with a black substance which was found to be bitumen. This mortar or cement is very hard and perfectly white in color. It will be observed that in both of these Phœnician mortars the lime is almost completely carbonated.

	Temple.	Cement.
Lime,	26·40	51·58
Magnesia,	·97	·70
Sulphuric acid,	·21	·82
Carbonic acid,	20·23	40·60
Sesquioxide of iron,	·99	—
Alumina,	21·6	·40
Silicic acid and fine sand,	16·20	·96
Coarse sand,	3·37	—
Small stones,	28·63	—
Organic matter,	·56	·24
Water,	·54	3·09
	100·26	98·39

Ancient Greek Mortars.—The first specimen is taken from a part of the Pnyx, the platform from which Demosthenes and Pericles delivered many of their orations. It has been long exposed to the action of the weather, is very hard, and of a greyish-white color. The other specimen is plaster from the interior of an ancient temple at Pentelicus, near Athens. It has not been exposed to the weather, the temple being in a cave; it is of a pale cream color, and moderately hard. The analytical results are the following:

	Pnyx.	Temple at Pentelicus.
Lime,	45·70	49·65
Magnesia,	1·00	1·09
Sulphuric acid,	—	1·04
Carbonic acid,	37·00	38·33
Sesquioxide of iron,	·92	·82
Alumina,	2·64	·98
Silicic acid and sand,	12·06	3·90
Water,	·36	3·07
	99·68	98·88

In the mortar from the Pnyx the carbonic acid is exactly the amount required by the lime and the magnesia, supposing both to be completely carbonated; in that from the temple, the carbonating is nearly but not quite complete.

Ancient Roman Mortars.—These differ from those already mentioned in being evidently prepared by mixing with burnt lime, not sand, but puzzuolana, or what is commonly, although improperly, called volcanic ash. Of these, four specimens were examined, but two only of the analysis were completed, owing to deficiency of material. The first in the following table was taken from Adrian's Villa at Tivoli, near Rome; it is a tolerably hard and firm mortar, of a rather dark-grey color.

The second is plaster from the interior of a wall at Herculaneum; it is hard, evidently exposed on one side to the action of hot volcanic mud, and of a red tint. The third specimen is from the roof of the Latin tombs near Rome, of a pale reddish-brown color. The fourth is a cement or mortar from a mosaic forming the floor of the baths of Caracalla, Rome. All these mortars were hard and firm, and contained an appreciable amount of silicic acid in combination:

	Adrian's Villa.	Herculaneum.	Latin tombs.	Mosaic.
Lime, . .	15·30	29·88	19·71	25·19
Magnesia, . .	·30	·25	.71	·90
Potash, . .	1·01	3·40	not estimated.	
Soda, . .	2·12	3·49	not estimated.	
Carbonic acid, .	11·80	23·80	13·61	17·97
Peroxide of iron, .	4·92	2·32	1·23	3·67
Alumina, . .	14·70	2·86	16·39	10·64
Silicic acid and sand, .	41·10	33·36	36·26	30·24
Organic matter, .	2·28	1·50	—	2·48
Water, . .	5·20	1·00	8·20	5·50
	98·73	101·86		

General Remarks.—These analyses appear to show that the lime in mortars and plasters becomes, in the course of time, completely carbonated, and does not form a combination consisting of $CaO,HO + CaO,CO_2$, a conclusion that has been arrived at by some authorities. They also show that in all cases where the mortar is freely exposed to the weather, a certain proportion of alkaline or earthy silicate is formed, which in all probability confers additional hardness, and that those mortars are the hardest which have been long below ground. It is well known to builders that those walls are strongest that are built during a rainy season, and that when mortar dries quickly it becomes crumbly and possesses little binding power. When kept wet for some time, a small proportion of silicate of lime will be formed, which will not only make the mortar itself harder, but will unite it more firmly with the stone. It is curious that the mortar which is probably the most ancient, (the specimen from a Phœnician temple,) is by far the hardest and firmest; in fact, like a piece of rock. It is a concrete rather than a mortar, and its excellence seems to indicate that a large grained sand is best for building purposes, and that even small gravel may, in certain cases, be used with advantage.

Mechanics' Institution, Glasgow.

Action of Sulphur in the Voltaic Battery.

M. Blanc, a young telegraphic operator in France, proposed to the Directors of the telegraphs a new pile which is described as follows by M. Matteucci:

"M. Blanc showed me a pile formed by a plate of zinc immersed in salt water with a sheet of lead galvanically covered with copper. The circuit having been closed, with a galvanometer in circuit, and the needle being settled at 0°, M. Blanc adds some 15 or 20 grammes of flour of sulphur to the liquid, and stirs so as to make a thin paste. At once the needle begins to rise, and after some hours attains the same deviation as though a plate of copper had been employed in a cell fitted with sulphate of copper, in place of the sheet of lead."

M. Matteucci, after satisfying himself that this pile gives a current nearly as strong as a Daniell battery, and constant for four or five days, during which the current was permanently closed, studied its phenomena, and he communicated his results to the Academy of Sciences at Paris. His conclusions are as follows:

First. Sulphur, in a state of powder, placed in contact with the electro-negative elements of a pile formed of zinc, copper, and a solution of sea-salt, augments considerably the electro-motive force, the constancy, and the duration of the battery. It may be hoped that by the use of sulphur a voltaic combination may be obtained presenting some advantages over the batteries now generally used in the arts.

Secondly. The sulphur, although insoluble and non-conducting, enters into combination with the sodium set free by the current. There remains to be explained the action exerted by a very small quantity of sulphuret of copper which is shown by experiment to be indispensable.

Hot-air Engine.

MM. Burdin and Bourget present for the opinion of the Academy of Sciences of France a plan of hot-air engine from which they believe an economy of at least one-half the fuel may be obtained, and which they desire to construct and experiment upon at the expense of the government.

The plan has simplicity at least. "Let there be an ordinary furnace, such as is used for steam engine boilers, the products of combustion of which escape into the chimney after descending along an inclined plane. Let the atmospheric air be first compressed to two atmospheres in small parallel tubes lodged in the flue, the air entering at the lowest point and consequently rising." Then follows a very rational calculation of the length and diameter of the tubes necessary, and a more complicated account of the engine. The theory is excellent; if it should succeed in practice we will return to it.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, May 18th, 1865.

The meeting was called to order with the President, Wm. Sellers, in the chair.

The minutes of the last meeting were read and approved.

The minutes of the Board of Managers were reported, as also those of the Standing Committees, and the following donations were reported: From the Royal Astronomical Society and the Society of Arts, London; the Canadian Institute of Toronto, Canada; the Nova Scotian Institute of Natural Sciences, Halifax, Nova Scotia; the Young Men's Association, New York; and from Alexander Brown, Esq., Joel Giles, Esq., and Prof. J. F. Frazer, Philadelphia.

The Committees on Weights, Measures, &c., reported progress. The Committee on steam expansion reported that the experiments with the first cylinder had been completed, and that those with the second were, at the time of speaking, just begun. The Committee on petition to City Councils with reference to the appointment of an inspector for steam boilers, reported that their petition had been presented, and were discharged.

The chairman of the Committee on Meetings, Prof. F. Rogers, then introduced Mr. Strickland Kneass, who read a paper as follows, on the

Bridge over the Schuylkill River at Chestnut St., Philadelphia.

This bridge is designed for two arches of 185 feet span each, over the water-way, and two in the approaches upon each side of the river, with spans of 60 and 53 feet. On the eastern side there is an additional arch over Twenty-fourth St., the carriage way of which is spanned by an arch of 26 feet, with 8 feet 6 inches rise, and a 7-feet simicircular arch over each footway. The shore spans are segmental arches with versed sines relatively of 18 and 16 feet. The street arch is five centred. See Plate V.

The approach on the east, which is in part sustained by retaining walls, is 595 feet long, from the west line of Twenty-third St., on the east, to the east abutment, measuring from abutment face, and on the west 547½ feet long from the east line of Thirtieth (Bridgewater) St., to west abutment face. The pier is in the middle of the river, about 50 feet west of the channel, and stands about 5 feet in its length (73·57 feet) askew with the general direction of the river at that point, with a width of 16 feet at springing line. The distances between pier and abutments are 185 feet, thus giving a total length to the structure, inclusive of approaches, of 1528½ feet.

The main spans are intended to be segmental arches of cast iron, with a versed sine of 20 feet, the ribs to have a depth of 4 feet, with a sectional area of 147·5 square inches each, which, with six ribs, will give 885·0 square inches of resisting area to each span.

The abutments are 42 feet 2 inches on length of road-way, and 55 feet 2 inches wide at springing line; with three horizontal cells in each, arched at both ends, the thickness of solid work at springing line on face being 16·5 feet, and on back, from which the first stone arch springs, 8 feet. The cells are each 7·5 feet wide, with piers 4·6 wide between. See Detailed Plans, Plate VI.

The masonry in main abutments and pier, as well as the abutments and piers of approach arches, are faced with closely cut granite, from the quarries of Fox Island, off the coast of Maine, near Rockland; it is laid with the Flemish bond (or alternate header and stretcher), with face "dabbed" and "drafted"; no stretcher has less than 2 feet bed and 6 feet length, no header less than 4 feet length with 2 feet face, the courses varying in thickness from 20 inches to 2 feet. The backing, which is from the Leiperville quarries, is generally laid with roughly dressed beds and builds, in no case having a level surface across the work; this arrangement was also carried out upon the main pier and approach abutments.

The site of bridge was occupied by wharves, and much labor and difficulty was experienced in arranging for the coffer-dams, preparatory to the excavation for abutment foundations. Upon the eastern side the rock is at a depth of 20 feet below ordinary high water, and upon the face line of work bare of earth, and well adapted in its surface for a coffer-dam. As far as practicable the material at site of abutment was dredged out before the coffer-dam was placed.

It was about 87 feet long on face, 23 feet deep, and 9 feet thick, with wings 8 feet wide running back fifty feet into the shore, built of wharf timber laid close, with ties every 8 feet in each course, dovetailed into sides, with interior braces to resist outer pressure; the wings were in part sheet piling secured with walling pieces.

The filling or puddling for dam was entirely gravel as it came from pit, yet not what would be called "clean gravel." The rise of tide is 6 feet, which gave 14 feet water at low tide. The dam was remarkably free from leaks, and was kept clear by a few hours use per day of a 6-inch Alden's (centrifugal) pump, driven by an Archambault portable engine, at a speed of three hundred revolutions per minute.

The rock was leveled in three benches, the back of abutment being 5 feet higher than the face. (Immediately at back of abutment was found the face of wall that formerly enclosed the basin from which, in early days, water for city supply was pumped.)

The western abutment is situated upon what was the river flats, the rock, from its inclination westward, running there to a depth of 38 feet below high water, was covered with a 5-feet stratum of gravel, and twenty-seven feet of marsh mud.

We here commenced operations after the old wharfing was removed, by driving piles over the area to be built upon; beginning at the back course (of necessity), and working forward; the design was to use hemlock, but the lower stratum of gravel was so compact that it was impossible to use them without their breaking before reaching the rock, or so brooming at their heads as to prevent a solid bearing; they were thrown aside and white oak adopted. Where the rock could not be reached by the piles, the limit for driving was to allow a 20-feet fall with a 1200 pound hammer, giving ¾-inch penetration. *Arch. and Eng. Journal*, 1852, page 37. ¾-inch will bear with safety 48,000 ℔s. This was determined from the practical experiments made by Major Saunders at Fort Delaware, which was the best data at hand, and proved to be perfectly reliable, as the abutment has stood firm and level. The greatest weight upon each pile with superstructure in position will be 40,000 pounds.

After the piles were driven, a coffer-dam, similar to that described for the eastern abutment, was constructed, which, being pumped out, the piles were cut off at an elevation of 2 feet below low water, except the first four lines from the front, which were cut at 6 feet. The mud was then excavated from around the pile-heads to a depth of 2·5 feet, and replaced with béton, composed of hydraulic cement, coarse gravel, spawls, and brickbats; proportions, one part cement, one part sand, three parts stone or gravel. This was carefully leveled at pile heads when a 12×12 squared white oak sill was set laterally upon the pile heads; coarse grouting was then poured into all the interstices, so as to make the bearing of sills equal upon both piles and béton; upon the white oak sills were placed 12×12 hemlock squared timber with spaces of three inches between each stick, gained three inches upon the oak sills, and bolted through to pile head; all the openings were, as before, filled with grout made of hydraulic lime, in proportion of 1½ of sand to 1 of cement, varying somewhat with the quality of the cement. Upon this platform was commenced the masonry, which was laid in hydraulic lime to a point above high water, after which the face joints were lipped with cement and the interior grouted with lime mortar.

The foundations of the western approach pier and abutments were prepared in the same manner.

The piles were driven 2½ feet from centre to centre, requiring 397 for main abutment, and 194 in the approach pier and abutment. There were about 8 miles in length of piling driven, including the retaining wall foundations.

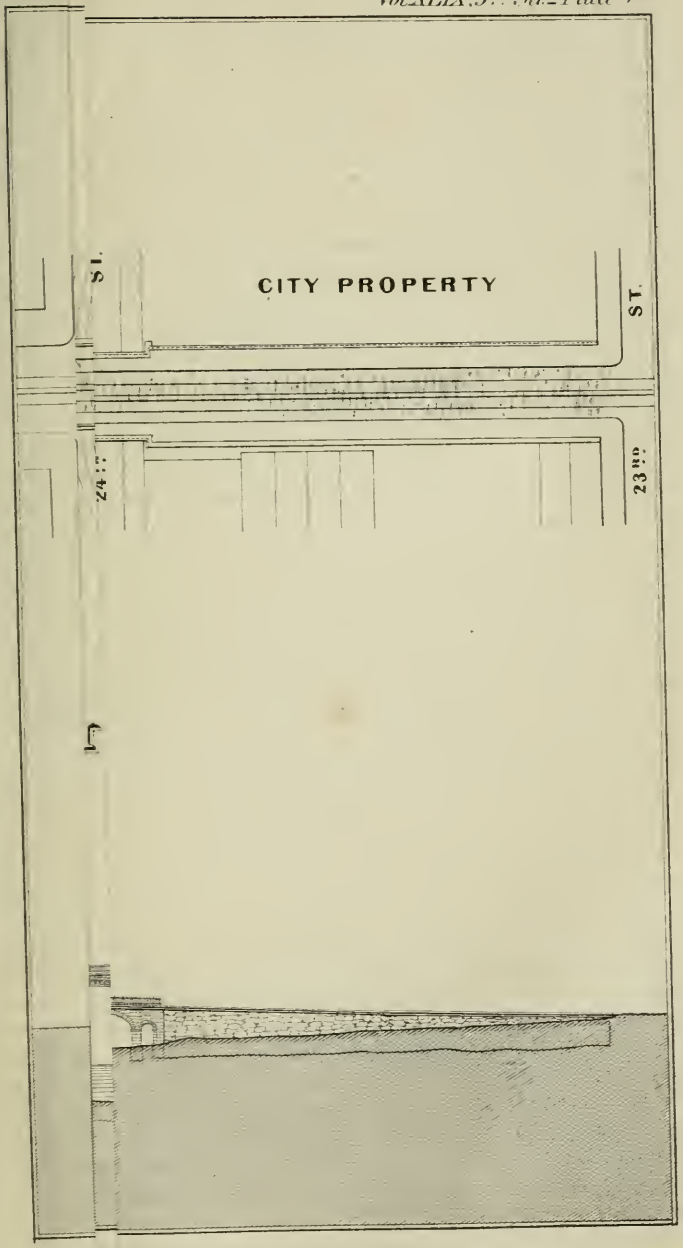
The pier is located in the middle of the river, and erected upon a crib foundation, (Plate VI,) made of 12×12 inch yellow pine timber carefully squared; it is 28 feet high, at base 86½ feet long, and 31 feet wide; at about 7 feet below low water it is 79½ feet long and 24 feet wide, reducing with a regular batir from base. At this point there is an offset of one foot all around, and is then continued up plumb for a further distance of 5 feet, finishing at 3½ feet below low water. In plan it is divided into 66 cells, having 17 courses crosswise, and 8 courses lengthwise. The greater portion of these cells are entirely open to the river bottom, only a sufficient number being platformed to contain the sinking weight which is placed on the second course from the bottom. Each course of timber was notched and bolted to prevent lifting or sliding, and laid together as closely as carefully counter hewed timber can be placed. It was built alongside of the pier site, and loaded as the work progressed, so that its top, while building, was always at water surface.

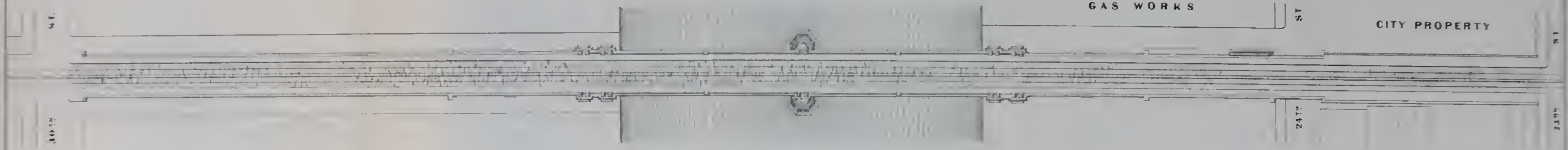
In preparing for the crib, it was ascertained by sounding that there was comparatively a level rock bottom, covered with about 8 feet depth of gravel. This was removed by dredging, when a framework was constructed, conforming to shape of crib and showing the position of each line of timber, in both directions upon the bottom courses; this was floated to and accurately anchored in position upon the pier site, and from it the soundings to rock were made along each line of timber as proposed. These were reduced to a common data by tide observations taken simultaneously with each sounding, thus giving a correct topographical plan of the rock surface, upon which the crib must set when in place, and to conform to which the bottom of crib must be constructed, to give, when in position, a top surface (level) for the commencement of the masonry. When prepared to set, the crib was floated to position, which was defined by a wire stretched between the abutments upon the centre line of bridge (then partially built), having a plummet hanging at the middle. Its line up and down the river was fixed by a point previously established on the railing of Market St. bridge, (500 feet above;) upon the crib were uprights marking the middle at upper and lower ends, and also a middle point on the centre line. When, therefore, the plummet hung over the middle point, and the two end uprights ranged with the point upon the bridge above, the location must be as intended. There was no difficulty experienced in placing the crib as desired; guys were arranged at each end of crib, so as to change its position with reference to its right angle line to bridge, working against a timber float fixed between crib and the western coffer-dam as a centre fulcrum, its position with reference to centre line being regulated by a capstan upon a scow secured to the pier of bridge above which worked it up stream, while the falling tide allowed its dropping down stream; when hauled out to position, it contained 300 tons of stone, and at sinking 150 tons more were thrown into the platformed cells.

This was done in November, 1862, and was allowed to remain loaded with about 700 tons of rough stone, until the following spring, when the other cells were filled with 1216 tons of broken stone and coarse gravel screenings to within a few inches of the top, making a total of 1666 tons of ballast in crib. A close laid platform, 12 inches thick, was laid over it so as to take up an inclination of three inches in its width, and enable the stone courses to start with level beds.

This platform was 2½ feet below low water, and had secured upon it a line of light timber laid to conform to shape of pier, so that the platform being accurately set and secured in position upon the crib, the masons need have no further guide (being below water level) in placing the stone cut to size and shape, than by being assured that they were full against the timber set to regulate them.

In the construction of this crib, much thought was given and inquiry made, to form some idea as to how much the top elevation would be reduced, by the weight of finished pier closing up the joints, and compressing the timber, which, from long immersion, would be water-soaked and swollen; this was important, for it was desirable to finish the springing line of the arches at the same level with the abutments without interfering materially with the courses of stone as laid out, and the stone-cutters should have the dimensions of the courses in hand to prevent unnecessary delay. Nothing could be found upon which an opinion might be based, but an allowance in its constructed height was made, which proved to be as near correct as could be hoped for, and caused but little adjusting of the courses as the work proceeded. The compression was as follows:


CITY PROPERTY
24TH ST.
23RD ST.



PLAN AND ELEVATION OF BRIDGE OVER THE RIVER SCHUYLKILL AT CHESTNUT ST.

PHILADELPHIA

1865.

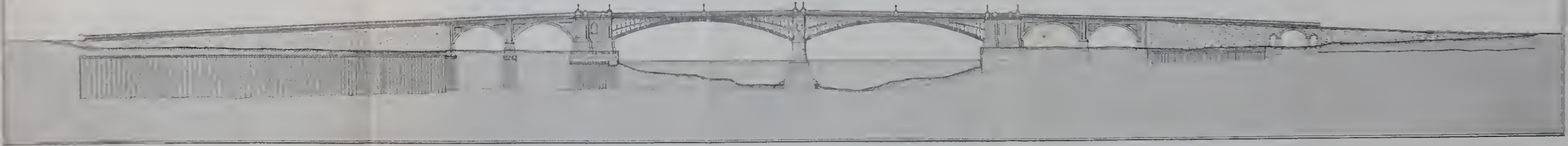
STRICKLAND KNEASS
Chief Engineer & Surveyor

JAMES R. McCLURE
Ass't Engineer

John R. Dye Draughtsman

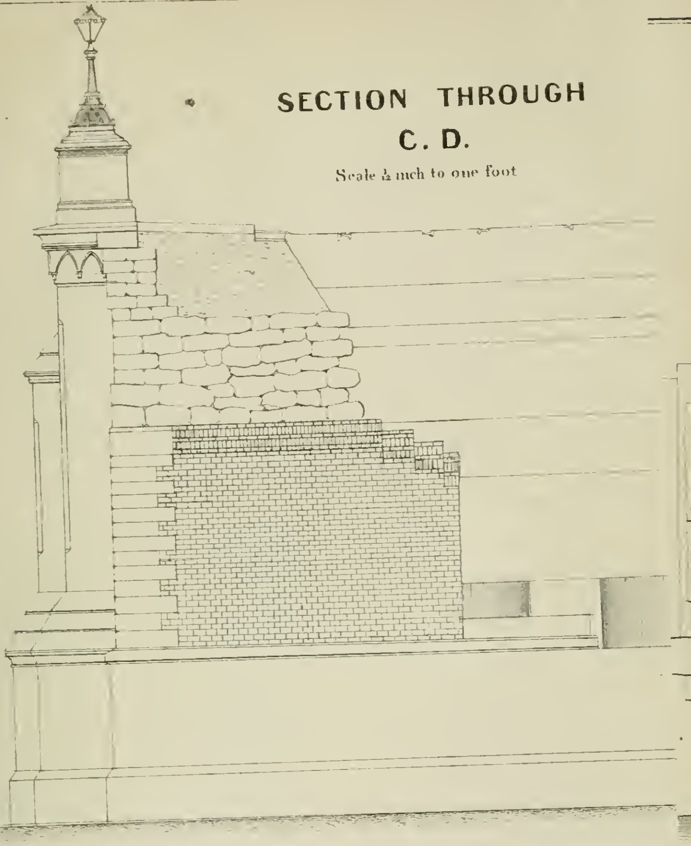
Scale 100 Feet to one inch

Jas McGuigan lith

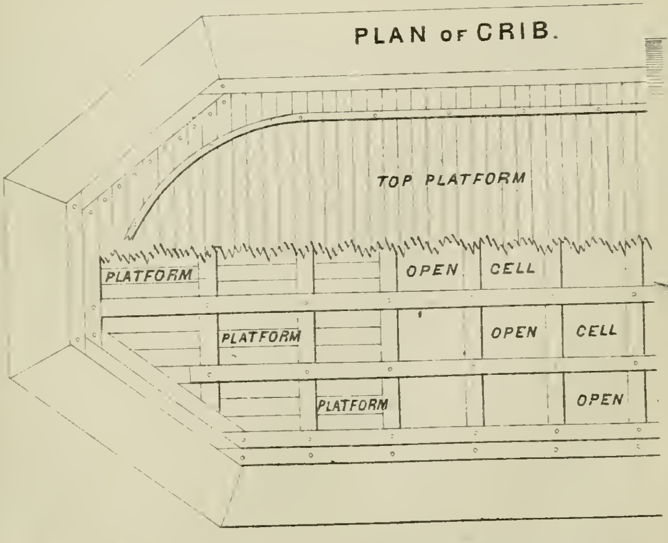


SECTION THROUGH C. D.

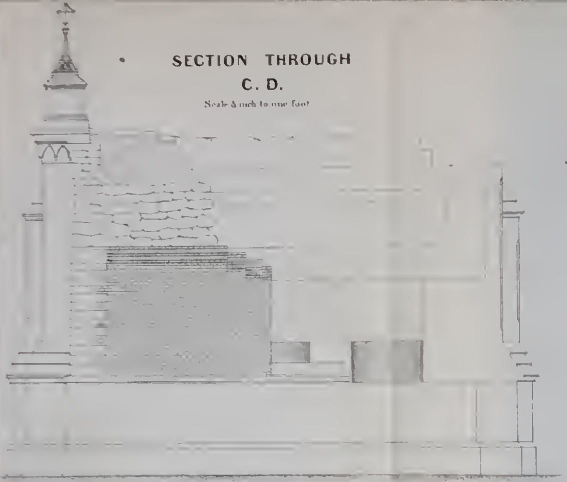
Scale ¼ inch to one foot



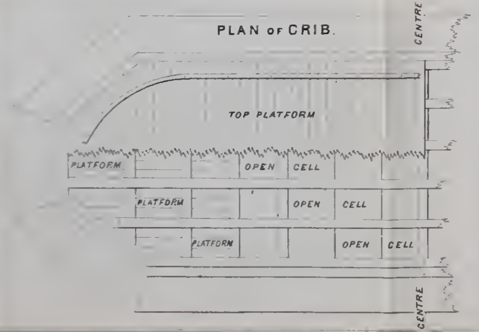
PLAN OF CRIB.



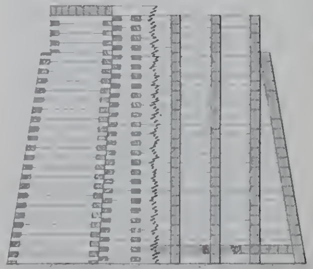
SECTION THROUGH
C. D.
Scale [illegible] inch to one foot



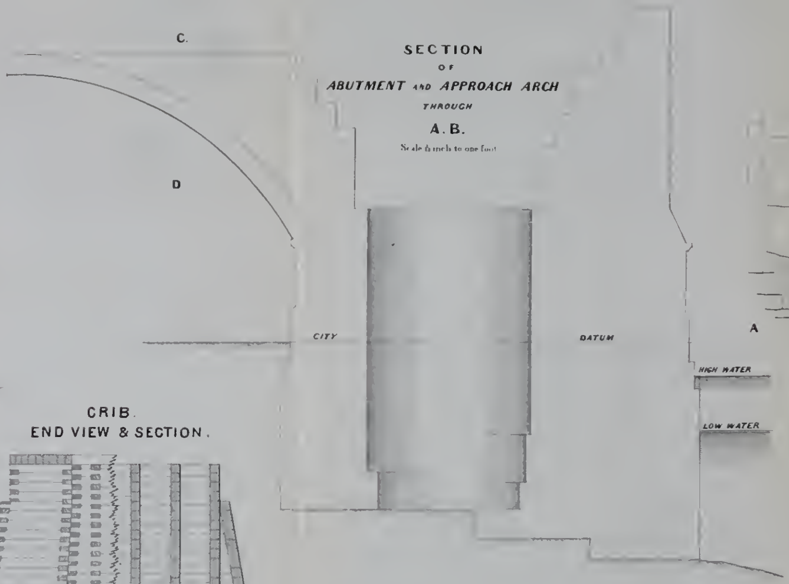
PLAN OF CRIB.



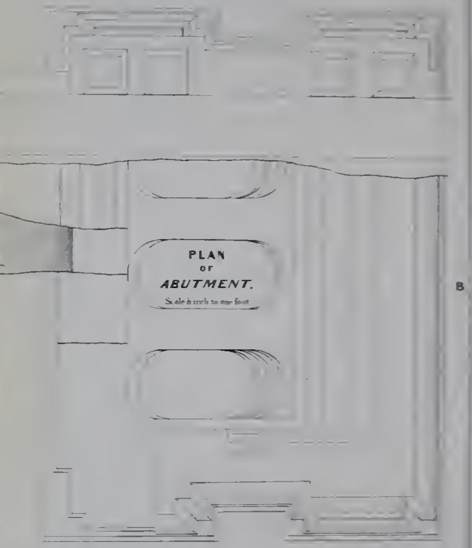
CRIB.
END VIEW & SECTION.



SECTION
OF
ABUTMENT AND APPROACH ARCH
THROUGH
A. B.
Scale [illegible] inch to one foot



PLAN
OF
ABUTMENT.
Scale [illegible] inch to one foot



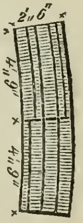
With 380 tons,		Compressed	$\frac{9}{16}$	of an inch.
"	726	"	"	$1\frac{1}{2}$	inches.
"	860	"	"	$1\frac{5}{8}$	"
"	1134	"	"	2	"
"	1268	"	"	$2\frac{5}{16}$	"
"	1529	"	"	$3\frac{3}{8}$	"
"	2131	"	"	$4\frac{1}{8}$	"
"	2237	"	"	$4\frac{7}{16}$	"
"	3020	"	"	$6\frac{1}{2}$	"
"	3255	"	"	$6\frac{1}{2}$	"

What proportions of this were consumed by the small irregularities on the bottom, there is no means of ascertaining.

The total weight of masonry in pier is 3255 tons.

The retaining walls are built of rubble work. From Twenty-third to Twenty-fourth Sts. the foundation is upon gravel; the remainder on the east side, or between Twenty-fourth St. and the approach arches, and on the west side entire from the west abutment of the approach arches to Bridgewater St., 378 feet, is upon piles. They are driven in three rows, varying in distance apart from four feet to five feet, proportional to the height of the wall. The level of the foundation platform is at mean tide, and is made of 12×12 inch hemlock stringers set upon the pile heads, and covered with hemlock plank 6 inches thick, bolted through stringers into each pile head; they are laid closely and transversely with line of wall. The walls are proportioned to ·3 of their height at $\frac{1}{3}$ from platform, and built with a batir of 0·1 per foot; instead of béton around the heads of the piles under retaining walls, sand was used to equalize the bearing; the piles here reach the rock and are 40 feet long below the platform.

The approach arches are laid with a thickness of 2·5 sheeting, faced with granite ring stone, the interior being brick. The brick-work is not laid in concentric rings, but built up so as to form voissoirs of a length of 4 feet 9 inches on the arch at intradoes; the bricks were laid wet with as close joints as is judicious with brick-work, and in their courses, to conform to the width of the ring stones on intrado, which was $14\frac{5}{16}$ inches; they are alternately $2\frac{1}{2}$ feet and $3\frac{1}{2}$ feet long. In putting up this work an attempt was made to prevent the cracks which ordinarily occur in a brick arch where it is faced with stone, by building the outer ring and brick sheeting up simultaneously, as is usual, closing the brick arch, but filling the place of the keystone in the outer ring with wood, hoping that when the centering was let down, the less motion in the rings in comparison with the brick-work, owing to the fewer and closer joints, would be compensated for through the different joints of the ring, and be taken up by the compression of the wooden key, and thus give a uniform pressure on the brick and stone. This was not attended with success; for although no cracks of any moment were apparent in the brick-work, yet the closing of its many joints did not divide its motion among the voissoirs composing the outer face, but moved the arch of ring stone entire upon its spring, and placed the bearing upon the inner



edge or intrado. The result was that several of the stones at the spring flushed on their inner face sufficiently to bring the back of voissoir to its bearing. This did not in any way affect the stability of the arch, but proved the great difficulty and care required in combining stone rings, laid as they usually are, with close joints and brick sheeting. In turning the western arches a further attempt will be made to combine the two classes of masonry by making larger joints between the rings.

There was none of this difficulty in erecting the arch over Twenty-fourth St., which was built with brick and stone, and is perfect in its inner surface, although the key was placed in at the same time the brick-work was closed. This was probably caused by the more open joints of the rings, and the shape of the arch, which is a five centre, while the others are segmental.

The approaches will be upon an ascending grade from Twenty-third St., westward 110 feet, 2·24 feet per 100 feet, then 220 feet, 4·0 feet per 100, then to the bridge abutment 3·2 per 100; upon the bridge itself the grades will form an arc of a circle 4900 feet radius, rising 2·35 feet per 100 from abutments to middle of span, then 0·6 per 100 to the pier, making the level of pier 2·75 feet higher than the abutments. From the west abutment to Bridgewater St. the grade descends at the rate of 4·0 feet per 100.

The carriage-way of the approaches and superstructure will be paved with granite blocks, having a width of 3½ inches and not less than 8 inches long laid in courses; they will be 5 inches deep and laid upon a 12-inch bed of anthracite coal ashes covered with 4 inches of clean gravel; the footway to be of brick laid in the usual mode.

The width of carriage-way will be twenty-six feet, or the same as Chestnut St., on the east, of which it is a continuation, with footways of 8 feet.

This work was commenced Sept. 19, 1861, and the first stone for the erection of the bridge was laid Dec. 17, of the same year, but, owing to the difficulty of obtaining material and labor, its completion has been much delayed. The masonry here described was ready for the superstructure in June, 1864, but, owing to continued delay at the iron works from the want of machinery, &c., the construction of the "false works" preparatory to the erection of the superstructure has but lately been commenced, yet we may, with some confidence, hope that the entire work will be completed during the coming autumn.

The magnitude of this work may be understood when we state that there are 573,415 cubic feet or near 23,000 perches of stone laid in the abutments, piers, and approaches, 99,000 cubic feet of which are carefully and accurately cut granite, the Gothic ornamental cornice and entablature being in style to conform to design of bridge superstructure, as is also the general plan of the abutments.

Messrs. Clark, McGrann and Kennedy are the contractors for the stone work. Their final estimate will be about $355,000, and it is but proper to say, that had not the rebellion, which broke out April 14th, 1861, shortly before the beginning of this work, so increased all values of labor and materials as to require an advance by the city of 27½ per cent. upon the schedule of prices in the contract, the first estimate of the work herein described would have been several thousand dollars less than the original estimate.

At the conclusion of the paper, some questions were asked and answered, as follows:

Prof. Fairman Rogers.—To what fact is due the non leakage of the dam? Was the dam itself tight? or was the gravel so dirty as to serve the purposes of stopping the leaks? This is the first instance of this kind I have ever noticed.

Mr. K.—We have found that gravel as *taken from the pit* makes better puddling for our coffer-dams than the mixed clay which we ordinarily procure. I attribute the tightness in the present case, however, not only to the use of gravel, but also to the simple fact of using the wharf-timber, laying it closely with fewer joints. The old-fashioned method of constructing these coffer-dams, was to make an expensive frame-work, with many lines of timber, and then sheeting up and down, which makes a great many joints.

Prof. Fairman Rogers.—Again; I don't exactly understand how the béton was confined at the western abutment.

Mr. K.—After the piles had been cut off level, the space between them was excavated to a depth of 2½ feet below the pile-heads, and where the mud was not sufficiently firm around the outer edge of piling to form a bank to hold the béton in place, we drove sheet piling. But this was required only for a length of some six or eight feet. The western approach pier foundation is of the same character.

SECRETARY'S REPORT.

Engineering Works.—We have to notice, under this head, the sinking of a new artesian well in Paris, at the place Hébert. Great and unexpected difficulties have been encountered in this work. At a depth of about 70 feet, a quicksand was struck, which occasioned a deflection in the tube lining, used for enclosing the well shaft, on account of which it had to be drawn up, and masonry, in successive rings supported on wooden curbs, substituted. A depth of 118 feet only has now been reached, but the progress seems likely to be more rapid and substantial in future.

Of a different character, as regards ease of execution, has been the advance of the Chicago tunnel, under lake Michigan. This has advanced nearly ⅓ of a mile under the lake, through an uninterrupted stratum of tough clay. Some boulders have been encountered, but these have been removed, piecemeal or entire, without serious drawback, and the work has throughout progressed with most gratifying facility. It was intended to cut this tunnel from three faces, by sinking a coffer-dam about a mile from shore, and then working both outward and inward from this point. This was, however, prevented by a variety of causes, and the work has been carried out thus far from the shore face alone.

Mechanical Engineering.—We observe a patent lately issued for the construction of the "units" (used in the spherical or Harrison boiler fully described, vol. xlviii, p. 38, of the *Journal*) from wrought iron, by the process of pressing with a large die.

We thus see the possibility of employing the strongest material for this strongest shape of steam generator, and thus attaining a combination of unprecedented endurance.

In the last number of the *Annales des Mines*, we notice an excellent article on smoke burning locomotives for bituminous coal, in which the economy and usefulness of this arrangement, is well exhibited in the results of some experiments on the railroads of the East and of Orleans. The combustion is rendered thorough in these engines by the use of an inclined grate, down which the fuel is gradually fed, as it consumes, and a fire bridge of refractory material, leaving a large combustion chamber for the gases before they enter the tubes. We would call attention in this place to a report on coal burning locomotives, made to the Pennsylvania Central Railroad Company by Mr. (now General) W. J. Palmer, some years since. Here the employment of a bridge of fire-brick is strongly advocated, on the ground that it acts as a reservoir of heat, keeping up the necessary temperature, when, from opening the furnace door, in stoking, &c., it is most needed, to insure the inflammation and combustion of the chilled gases. The curious fact is noticed in this report, that the amount of fuel yearly thrown away as smoke, on such a road as the above, is in the neighborhood of *seventy tons*.

Mechanics, Theoretical.—Prof. Rood, of New York, has shown that if a gyrascope, while spinning, is made to revolve about the line which is common to the plane of its wheel and ring, (which motion would tend to develop a pressure alternately in opposite directions upon its supports,) its moving force will be taken up by this action, and in place of running 16 minutes, for example, it is brought to rest in about 20 seconds. Opposing motions or forces, as we know, destroy each other in a mechanical sense, or, in other words, are changed in form, as into heat, &c., but the above illustration is a very striking, neat, and clear means of demonstrating the fact of this destruction, and of exhibiting it in a new light. For details, see *Silliman's Journal*, May, 1865, p. 259.

Our attention having been drawn to a misprint in a previous volume of the *Journal*, we take this opportunity of correcting it. In the description of J. Harrar's skate fastening, vol. xlviii, p. 426, the sentence should run, "securing the skate to the heel of the shoe or boot."

Physics, Electricity, Thermo-electric Piles.—Bunsen has published an account of a new combination, consisting of native copper pyrites and an alloy of, antimony 2: 1 tin; or of pyrites and copper, by which a greatly increased thermo-electric force may be developed. Such an element heated to 60° Cent., and to the melting point of tin, at its opposite ends, gives a force ten times greater than that of a bismuth and antimony element at the temperatures of 0° and 100° C. It is requisite, however, that the pyrites should be used in its natural state. If fused and cast it loses all its efficiency. Pyrolusite (MuO_2) and platinum are also found, by this same experimenter, to give a powerful current, though opposing great resistance to its transmission.—*Silliman's Journal*, May, 1865, p. 219.

In another article (p. 205 of the *Cosmos*, Feb. 22, 1865) we see an account of various experiments in the above direction, made by M. E. Becquerel, and by his father, at various dates from 1827 to the present time. From this it would appear that a copper wire sulphuretted (sulphuré) on the surface, would form with pure copper an energetic thermo-electric pile. M. Becquerel has exhibited to the Academy, the model of a pile, constructed according to his directions, of metallic copper and its sulphide. In this, each element consists of a plate of CuS_2, about 3 inches long, $1\frac{1}{2}$ inches broad, and $\frac{3}{8}$-inch thick, provided with caps of copper at each end, which are connected in such an order by copper rods, that one end of the group being heated and the other cooled, a current may be established.

It would appear from the article above quoted, that artificial *sulphide of copper may be used* in an efficient thermo-electric pile. We would suggest in this connexion the question: Is there not some chemical action, as well as one purely thermo-electric, in the use of this combination?

In the proceedings of the Royal Irish Academy, we see the description of a Ruhmkorff coil, made with iron wire for its outer helix, wound in three flat rolls or block wheels; 30 miles of $\frac{1}{100}$-inch wire are used, and the spark obtained is 16 inches. This coil was constructed by Dr. Collan, of Maynooth. The use of iron wire, in such a case, seems judicious in certain respects, its resistance or low conducting power being, perhaps, advantageous; but the facts which have been brought to our notice, with regard to the giving out of small induction medical coils, made of this material, would make us anxious about the longevity of the apparatus in question.

Ruhmkorff coils of very minute proportions, but capable of demonstrating satisfactorily the properties of the induced spark, have been constructed by M. Gaiffe of Paris. Their efficiency, according to M. Du Moncel, results from the complete insulation of their various parts. The length of the bobbins is less than three inches, and the base on which they rest, and which carries or contains all the other parts, is $4\frac{3}{4}$ by 3 inches.

Light.—We state, for the benefit of those interested in the matter, the details of apparatus (lately used in the lecture brought out by the Institute, at the Opera House) for producing an artificial rainbow.

The light employed was the ordinary lime light, with hydrogen burned directly from a large "generator" provided with a Wolf's or washing bottle, and oxygen from a gas-bag, both under pressure of 15 inches water gauge, or about $\frac{5}{8}$-lb. per square inch.

A simple concentric jet and square prism of lime were employed, no adjustment of the latter being required during the limited time of the experiment.

This light was placed in an ordinary magic lantern box, with two $4\frac{1}{2}$ inch condensers, having a combined focus of 2 inches. A single, meniscus, uncorrected object lens, of 7 inches focus and $1\frac{3}{4}$ inches aperture, completed this apparatus. In the usual place for the object or picture was inserted a brass plate, having an arched opening, with a span of $2\frac{3}{8}$ inches, and a radius of $1\frac{5}{8}$ inches on the outside, (therefore, not quite an entire semicircle,) and a width of aperture of $\frac{1}{8}$-inch. A glass slide painted black, with the exception of a similar arch left clear, serves almost as well. The image of this arch being focused on the screen, about 50 to 60 feet off, the lantern is inclined upward at a great angle, and a hollow prism filled with bisulphide of carbon, is held across the front of the object glass, at the angle of least refraction. This hollow prism was made by grinding away two vertical edges of a square bottle, 2 inches on base by 3 inches high, and cementing plates of glass, on the skeleton wedge so obtained, with the mixture of molassess and glue used for "inking rolls." A *square* bottle was used out of deference to the recommendation in Frick's Physical Technics; but many difficulties were experienced in consequence, and we would recommend, and shall ourselves employ, in future, a stout, *round*, *German* bottle. To develop the effect of this experiment, in the case referred to already, the stage was set with wings to represent a forest, a low rock background, and a white "horizon drop" or rear curtain, which, by proper adjustment of the border lights (throwing it in shade) was made to appear of a graduated dark grey. On this the bow was thrown. The light and intensity of color of the bow was sufficient to allow of a very considerable general illumination of the stage, without bringing the rainbow below (if even *to*) the natural faintness.

We would call attention to the remarkable experiments made by Dr. Tyndall, on obscure heat, from the electric light, a full account of which will be found on a previous page of this *Journal*.

The Spectroscope has received a new and remarkable application, in the direction of astronomy. It has been applied to many of the nebulæ for the purpose of deciding the question of their solid or gaseous condition. Solid bodies incandescent (so highly heated as to give out light), produce a continuous spectrum, exhibiting, more or less clearly, the graduated series of the rainbow tints. Incandescent gases or vapors, on the other hand, (such as the diffused vapor of salt which will give a yellow color to the flame of alcohol,) show no continuous stripe of varying colors, but exhibit only certain defined bands or lines of colored light, characteristic in each case of the substance producing them.

The sun, as we know, gives in this sense a *continuous spectrum*, so do the stars and planets, so does a highly heated bar of metal or wire, and so do our ordinary flames of candles, lamps, gas, and the like, containing, as we know, countless particles of solid carbon, highly heated. We therefore conclude or know, that all these are *solid* sources of light. But flames which do not contain solid matter, carrying only vapors in an incandescent state, such as the alcohol and salt above mentioned, the flame of hydrogen tinged by phosphorus, &c., give us simply isolated and distinct bright lines.

It will be readily seen, therefore, that when, on turning the spectroscope upon the famous dumb-bell nebula, we find three bright lines only visible, we have good reason to conclude that this body is not a grand system of suns at an immense distance, but only a diffused hot vapor, possibly near at hand. Some of the nebulæ give us, however, continuous spectra, and these, therefore, retain their place in our estimation, as far-off clusters of suns.

Several nebulæ, completely resolvable, and whose stellar character passed unchallenged, have yielded the secret of their structure to this new questioner. Among these is the famous nebula in the sword-handle of Orion, the annular nebula in Lyra, and the dumb-bell nebula mentioned above.

For a full account of the observations leading to these results, we would refer to a paper by Mr. William Huggins, in the proceedings of the Royal Society, vol. xiv. p. 39, and a paper communicated by Father Seschi to the French Academy of Sciences. *Comptes Rendus*, vol. lx, p. 466, (March 6, 1865.)

Chemistry.—If a small amount of iodine is added to fused sulphur, the whole heated to about its boiling point, and then poured in a thin stream into cold water, it will assume the amorphous or plastic form, as might be expected, but with certain differences of properties as compared with pure sulphur under like treatment. Thus, it is of a rich garnet color, *very* plastic, and agglomerates readily, so that it can be easily worked into a consistent mass; it will retain its plasticity for a much longer period than pure sulphur, not entirely loosing it until about three days after its preparation. A similar result is stated to follow the addition of wax, oil, naphthaline, creasote, camphor, turpentine, &c. All but the first two, moreover, rendering the sulphur insoluble in bisulphide of carbon. Carbon prepared from sugar or from wood, produces like effects, even in so low a proportion as 1 : 1000 parts of sulphur. For full particulars see paper in *Comptes Rendus*, vol. lx., p. 353, (Feb. 13, 1865.) (Specimens of sulphur in its soft state, both pure and as above, were here exhibited.)

We have also to notice an important improvement in the process for revivifying animal charcoal used in sugar refining, lately patented, as we see, in England, by a Mr. Beanes. The "spent char," or charcoal which has lost its decolorizing properties by use, is first heated and dried, then exposed to a current of hydrochloric acid gas, (a large quantity of which it absorbs,) and is then mixed with a further quantity of heated "char," to which it imparts its excess of acid. By this means the lime from the syrup (which has choked up the pores of the charcoal and thus destroyed its efficiency as a decolorizer), is converted into chloride of calcium, which can be readily washed out, after which, the charcoal is reburned, as usual, to remove albuminous matter, and is then found to be in most excellent condition.—See *Chem. News*, Feb. 17, 1865, p. 76. We would call attention to the excellent remarks on this subject by Dr. Crace Calvert, quoted on page 250 *et seq.* of this *Journal*, April 1865.

In a paper read before the London Chemical Society, Dr. Calvert stated some important facts which had come within his notice regarding the destructive effects of silicate of soda upon cotton fibre when this salt was used as a "dressing to the fabric." The destruction of the cloth was unquestioned, although some uncertainty was expressed in the succeeding discussion, as to the chemical or mechanical cause of the injury, *i. e.*, whether it resulted from decomposition of the silicate and the liberation of caustic alkaline carbonate by the action of carbonic acid in the air, or from a mere crystallization of the salt within the fibres of the fabric.—See *Chem. News*, March 10, 1865, p. 113.

In connexion with this crystallization of a silicate, we would notice a curious experiment in the production of a pseudo-vegetation, analogous to that seen in the moss agate. An account may be found page 120 of the *Chem. News* just referred to, but we will here give a description of the best arrangement of the experiment according to the result of our own trials. A glass jar of any size may be filled with the commercial solution of silicate of soda, diluted by the addition of 5 times its volume of water, and into this should be dropped a few crystals (varying in size from that of peas to that of common chestnuts) of sulphates of iron and of copper. In a few minutes, branches of seeming vegetation (much like certain aquatic plants) will shoot up from these crystals, and in a few hours will reach the level of the liquid and show an extended development. This action is due to the solution of portions of the crystals from time to time, the rising of this solution in the dense silicate, and the union of the metallic base, with silica, to form a solid mineral silicate. The iron salt gives a seeming vegetation of an olive green, the copper of a light blue color. Their combined effect is very beautiful. A little *mineral aquarium* may thus with ease be prepared which will bear careful moving, (two of those, this evening exhibited, were carried half a mile in a basket an hour since,) last for an indefinite period, and serve as an admirable illustration of that process of diffusion or percolation, whose beautiful effects we observe in the moss agate.

We have also found that additional variety may be given by the use of sulphate of nickel, which produces a vegetation of a beautiful emerald-green color, and sulphate of zinc, which develops formations wonderfully like those of the lowest animal organism, such as the gelly-fish, the yeast plant as seen in the microscope, &c.

When the growth of these mineral plants is complete, the whole may be placed under a gentle stream of running water, (as from a spigot,) and the solution thus displaced by fair water.

The addition of chromate of potash to the solution does not, we think, improve the effect.

A convenient form of blow-pipe for organic analysis is described by Dr. Herapath in the *Journal of the London Chemical Society*, Feb. 1864, p. 49. It consists of an ordinary gas pipe, bent into a U form, of which the two limbs are close together. The upper surface of this is pierced with a number of small holes, and a branch pipe is provided, so that air may be blown from the mouth into this tube with the gas which enters it from the mains.

From an accident recorded in the same journal, it appears that in highly compressed oxygen, masses of iron, (such as the inner surface of a heavy steel receiver, for example,) will burn violently if ignited by such a body as oil, inflamed under like conditions.

We would call attention, lastly, to the translation of an excellent paper on the "Bessemer process of manufacturing steel from pig iron," just published in the *Bulletin* of the American Iron and Steel Association, by R. H. Lamborn, Secretary of the above Institution; and would offer some specimens of the steel which has been so prepared, both in this country and abroad, in a rough and manufactured form.

After the conclusion of the above report, Prof. F. Rogers proposed certain amendments to the By-Laws of the Institute, with a motion providing for their consideration at the next stated meeting, and the preparation of printed copies for the use of the members before that time.

The proposed amendments were then read by the Secretary, the motion was carried, and the meeting was, with the usual form, adjourned.

HENRY MORTON, *Secretary.*

BIBLIOGRAPHICAL NOTICES.

A Treatise on Astronomy. By ELIAS LOOMIS, LL.D. New York: Harper & Bros., 1865, 8vo. pp. 338.

It is but too seldom, upon our side of the Atlantic, that our text-books are written by men of competent knowledge in the science which they profess to teach. Hence, we generally find them to be either a loose combination of heterogeneous material taken from former books, or from the scientific annual, or else we have a dry and indigested mass of practical formulas, which, although useful to the technical artist, are but stumbling-blocks to the learner. The work before us constitutes an honorable exception to the rule. We have here a well arranged treatise upon the fundamental principles of astronomy, demonstrated simply but rigorously, and illustrated and relieved by an account of the physical phenomena of the universe which we believe with the author, to be well calculated to "enhance the interest of the subject," and which, indeed, to the general student of astronomy, are of quite as much importance as the mathematical laws of the system.

The arrangement of the subject is particularly good, and the treatment of each article is sufficiently full without being prolix. We are, however, a little surprised to notice certain omissions of recent researches in astronomy which must be familiar to one of Professor Loomis' information; such as the adherence to Encke's parallax of the sun (8″58) and the consequent distance (95,000,000 miles) of the sun from the earth. We had thought all astronomers were now agreed that the parallax must be increased to something like Leverrier's value (8″95), with which the recent determinations of Winnecke, Stone, and

Hansen very closely agree. A less remarkable omission is that of any mention of Faye's theory of the acceleration of comets, which favorably replaces Encke's resisting medium, inasmuch as it substitutes a familiar cause for an entirely hypothetical one. But these are but slight blemishes, and, indeed, are rather advantages in a text-book, as they serve to keep the teacher wide awake. We can safely and sincerely recommend this book to teachers as an excellent text-book, and hope it may be extensively used.

A Treatise on the Assaying of Lead, Copper, Silver, Gold, and Mercury. From the German of M. Bodemann and Bruno Kerl. Translated by W. A. Goodyear, Ph. B. Illustrated with plates. New York: John Wiley & Son, 1865, 12mo. pp. 214.

This handy little work is very seasonable here at present, when we are so largely embarking our capital in the development of the almost fabulous resources of our middle and western territory, and we think the translator has done well in reducing the size of his treatise by translating only those parts which relate to what used to be the rarer metals. The work of Bodemann and Kerl is of high authority in Germany; and in metallurgy especially, German authority is in the highest repute throughout the world. We earnestly recommend this treatise to the attention of all who are interested in the metals of which it treats. It purports to be published for the Berzelius Trust Association, and in the title and preface makes mention of the Sheffield Scientific School, both of which we suppose all men are bound to know all about, but of both of which we confess ourselves lamentably ignorant.

The Pulpit and Rostrum, a New York Serial, Published by Schermerhorn, Bancroft & Co. have published an extra number containing Hon. Edward Bancroft's Oration at the Obsequies of the Late President; the Funeral Ode, by Mr. Bryant; the Emancipation Proclamation; and the Inaugural Address for 1865; and Illustrated by a Portrait of Mr. Lincoln.

The documents are well and clearly printed, of a convenient size for preservation and reference, and we regard the publication of the Emancipation Proclamation, and the President's Inaugurals, and their wide diffusion throughout the people, as a matter of great importance, for they abound in sentiments which ought to become watchwords among us, and they appear to us likely to be cherished by succeeding generations as the farewell address is by us. The oration is, we suppose, a necessary diluent in all American ceremonies, as the nitrogen is in our atmosphere. The portrait seems to us to be, so far as likeness is concerned, one of the best we have seen, especially from its giving something of that remarkable expression of the eyes which was so characteristic a feature in the face of our martyred President. We hope this little publication will be widely diffused, as we feel sure that few, even in the party of his assassins, can read his sentiments without being, at least for the moment, better for them.

A Comparison of some of the Meteorological Phenomena of the SPRING, of 1865, *with that of* 1864, *and of the same season for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	Spring, 1865.	Spring, 1864.	Spring, for 14 years.
Thermometer—Highest—degree,	84·00°	86·00°	90·00°
“ date,	May 17.	May 10, 31.	May 7 60, 23 63
Warmest day—Mean,	75·50	78·17	79·83
“ “ date,	May 17th.	May 9th.	May 23d, '60
Lowest—degree,	24·00	20·00	4·00
“ date,	Mar. 11th.	Mar. 22d.	Mar. 10, '56.
Coldest day—Mean,	31·67	27·33	11·50
“ “ date,	Mar. 11th.	Mar. 22d.	Mar. 10, '56.
Mean daily oscillation,	14·04	15·19	16·05
“ “ range,	6·44	5·14	5·98
Means at 7 A. M.,	51·05	47·26	46·80
“ 2 P. M.,	61·11	58·00	58·09
“ 9 P. M.,	54·01	50·88	50·56
“ for the Spring,	55·39	52·05	51·82
Barometer—Highest—Inches,	30·265 in.	30·131 in.	30·522 in.
“ date,	Apr. 9th.	Mar. 3d.	Mar. 3d, '52.
Greatest mean daily press.,	30·208	30·090	30·458
“ date,	Apr. 9th.	Mar. 3d.	Apr. 3d, '54
Lowest—Inches,	29·185	29·184	28·884
“ date,	Mar. 22d.	Mar. 30th.	Apr. 21, '52
Least mean daily press.,	29·241	29·246	28·959
“ date,	Mar. 22d.	Mar. 30th.	Apr. 21, '52
Mean daily range,	0·162	0·135	0·161
Means at 7 A. M.,	29·821	29·705	29·822
“ 2 P. M.,	29·776	29·661	29·777
“ 9 P. M.,	29·818	29·706	29·809
“ for the Spring,	29·805	29·691	29·803
Force of Vapor—Greatest—Inches,	0·689 in.	0·714 in.	0·771 in.
“ date,	Apr. 29th.	May 24th.	May 14, '54.
Least—Inches,	·076	·064	·023
“ date,	Mar. 6th.	Mar. 20th.	Mar. 5, 1858.
Means at 7 A. M.,	·284	·263	·252
“ 2 P. M.,	·306	·278	·267
“ 9 P. M.,	·303	·286	·271
“ for the Spring,	·298	·276	·263
Relative Humidity—Greatest—per ct.,	96·0 per ct.	97·0 per ct.	100 per ct.
“ date,	Mar. 9, 31.	May 26th.	often.
Least—per ct.,	23·0	18·0	13·0
“ date,	Apr. 24th.	Mar. 9, Ap. 7	Ap. 13, 1852.
Means at 7 A. M.,	70·4	71·9	72·0
“ 2 P. M.,	53·8	52·4	52·0
“ 9 P. M.,	67·8	69·1	67·9
“ for the Spring,	64·0	64·5	64·0
Clouds—Number of clear days,*	21	21	28·2
“ cloudy days,	71	71	63·8
Means of sky cov'd at 7 A.M.,	66·7 per ct.	62·2 per ct.	60·8 per ct.
“ “ “ 2 P.M.,	68·4	68·6	63·0
“ “ “ 9 P.M.,	54·5	59·2	48·9
“ “ for the Spring,	63·2	63·3	57·6
Rain—Amount,	15·396 in.	18·763 in.	13·002 in.
No. days on which Rain fell,	37.	36.	36·6
Prevailing Winds—Times in 1000,	S62°34′W·172	N52°39′W·096	N70°39′W·181

* Sky one-third or less covered at the hours of observation.

A Comparison of some of the Meteorological Phenomena of MAY, 1865, *with those of* MAY, 1864, *and of the same month for* FOURTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By J. A. KIRKPATRICK, A. M.

	May, 1865.	May, 1864.	May, for 14 years.
Thermometer—Highest—degree,	84·0°	86·00°	90·00°
“ date,	17th.	10th, 31st.	7th 60, 23d 63
Warmest day—mean,	75·50	78·17	79·83
“ “ date,	17th.	9th.	23d, 1863.
Lowest—degree,	46·00	41·00	35·00
“ date,	1st, 2d, 12th.	3d.	7th, 1854.
Coldest day—mean,	50·50	49·67	40·00
“ “ date,	1st.	3d.	3d, 1861.
Mean daily oscillation,	13·81	16·61	17·00
“ “ range,	6·60	5·03	5·58
Means at 7 A. M.,	59·87	62·53	58·66
“ 2 P. M.,	68·91	73·35	69·85
“ 9 P. M.,	61·39	65·15	61·57
“ for the month,	63·39	67·01	63·36
Barometer—Highest—inches,	30·147 in.	30·000 in.	30·338 in.
“ date,	15th.	5th.	4th, 1852.
Greatest mean daily press.,	30·120	29·978	30·273
“ date,	15th.	5th.	5th, 1852.
Lowest—inches,	29·405	29·379	29·096
“ date,	22d.	10th.	27th, 1861.
Least mean daily press.,	29·447	29·437	29·243
“ date,	22d.	0·108	27th, 1861.
Mean daily range,	0·126	10th.	0·120
Means at 7 A. M.,	29·742	29·663	29·808
“ 2 P. M.,	29·708	29·627	29·770
“ 9 P. M.,	29·740	29·665	29·795
“ for the month,	29·730	29·652	29·792
Force of Vapor—Greatest—inches,	0·683 in.	0·714 in.	0·771 in.
“ date,	20th.	24th.	14th, 1854.
Least—inches,	·143	·202	·069
“ date,	3d.	3d.	2d, 1861.
Means at 7 A. M.,	·380	·423	·359
“ 2 P. M.,	·389	·452	·376
“ 9 P. M.,	·402	·461	·382
“ for the month,	·390	·445	·372
Relative Humidity—Greatest—per ct.,	95.0 per ct.	97·0 per ct.	100 per ct.
“ date,	8th.	26th.	often.
Least—per ct.,	24·0	32·0	16·0
“ date,	3d.	28th.	5th, 1855.
Means at 7 A. M.,	71·7	73.2	71·4
“ 2 P. M.,	54·9	54·5	51·5
“ 9 P. M.,	72·0	73·6	68·7
“ for the month,	66·2	67·1	63·9
Clouds—Number of clear days,*	5	7	10
“ cloudy days,	26	24	21
Means of sky cov'd at 7 A. M.,	76·1 per ct.	62·9 per ct.	59·5 per ct.
“ “ “ 2 P. M.,	69·4	69·0	60 9
“ “ “ 9 P. M.,	54·5	58·4	47·0
“ “ for the month,	66·6	63·4	55·8
Rain—Amount,	7·692 in.	9·042 in.	4·829 in.
No. of days on which rain fell,	13	12	12·7
Prevailing Winds—Times in 1000,	S 74° 17′ W ·190	S 22°23′ W ·105	N 78°26′ W ·109

*Sky, one-third or less covered at the hours of observation.

INDEX.

PAGE.

Aerial Navigation,—Notice of a paper by Prof. P. H. Vander Weyde, 139
Air Engine,—Improvement in the Hot 412
Air prior to the Discovery of Oxygen,—On the Supposed Nature of 194, 333, 404
Alkalies on Cotton Fibres,—The Injurious Action of 402
Aluminium,—Preparation of 346
———— by Zinc, On the Reduction of 178
Armor Plating to Sides of Vessels,—J. H. Meissner's Bolt for 139
Assaying of Lead, Copper, &c.,—Notice of Bodeman and Kerl's Treatise on 426
Astronomy,—Notice of E. Loomis' Treatise on 425
Atalanta,—Particulars of the Iron Steamship 395
Atmospheric Pressure as a Source of Mechanical Power, 200

Battery,—New Electric 408
Bibliographical Notices—
  Treatise on Astronomy. By E. Loomis, 425
  ———— Assaying of Lead, Copper, Silver, Gold, and Mercury. By Bodeman and Kerl, 426
  Pulpit and the Rostrum, 426
Bituminized Paper Pipes and Roof Sheeting, 210
Bolt for Armor Plating to Sides of Vessels,—J. H. Meissner's 139
Boring Rocks,—Mushet on a Steel Suitable for 127
Bouton, (W.,) on the Economy and Safety of Different Modes of Traveling, 263
Bridge,—Description of a Steel 298
———— ———— the proposed Great Iron Girder 235
——— over the Schuylkill River,—S. Kneass' paper on the new 413
Briggs, (R.,) on a Uniform System of Screw Threads, 111
———— on the Proportions of Cast Iron Steam or Water Pipes with Faced Flanged Joints, 276
Building under water,—Method of 295

Candle,—Notice of J. Field's Improved 139
Caledonia,—Particulars of the Iron Steamship 394
Carriage Spring,—Notice of U. B. Vidal's Car or 139
Carriages,—Another Novelty in Cars or other 275
Catchment Basins in Rivers, 367
Cements, Mortars, and Concretes,—Haswell, (C. H.,) on Limes, 361
———— —On Hydraulic 407
Chemistry Applied to the Arts,—Lecture by Dr. F. C. Calvert on 246, 321
Cities,—On the Supply of Water to 45
City of Boston,—Particulars of the Iron Steamship 396
Coal Mines,—New Safety Light for 262
—— On the Use of Petroleum as a Steam Fuel in place of 130
—— Trade in Europe,—Statistics of the 345
——, Trial of a New Machine for getting 128
Condensers Superseded,—The Surface 331
Coppering Iron Ships,—On a Mode of 51
Cotton,—On the Chemical History and Application of Gun- 37, 133, 189
——— Fibres,—The Injurious Action of Alkalies on 402
Cranes and Hodmen in Paris,—Substitute for 130

Decimal Measure,—On the Relative advantages of the Inch and the Metre as the Standard Unit of 176
Dynamometer of the Royal Technological Institute at Stockholm, 392

Elastic force of Steam,—On the 371
Electric Light,—Tyndall on the Invisible Radiation of the 390
———— Cheap form of Automatic Regulator of the 179
Electric Battery,—A new 408
Electro Magnet,—Description of a New 406
Equation,—J. W. Robinson, the Use of the Double Eye-piece in the Determination of the Personal 388
Explosion,—Singular Boiler 400
Explosive Materials,—On the storing of 36

Fire-arms,—Improvements in 345
——, Means Adopted in the Lowell Factories for Extinguishing 268
——Service and Hydrants, 81, 168, 236, 288
Francis, (J. B.,) on the Means for extinguishing fires in the Lowell Factories, 268
Franklin Institute—
  Proceedings of Monthly Meetings, 53, 138, 212, 279, 346, 412
  Annual Report of the Board of Managers for year 1864, 140
  Election of Officers, Managers, and Auditors for 1865, 138
  Secretary's Reports, 214, 285, 356
  Description of Apparatus prepared for the Experiments on Steam Expansion, 280
  Geography and Geology of Petroleum,—A. Leeds' Paper on 347
  Photographic Process and its Applications,—J. W. Osborne's 57
  Screw Threads, &c.,—Report of Committee on a Uniform System of 53
  Bridge over the Schuylkill River,—S. Kneass' paper on the new 413

Gas,—Account of Apparatus and Process for the Chemical and Photometrical Testing of Illuminating 126
—— Carburetter,—Notice of U. B. Vidal's 140
Girder,—The Hydrostatic 398
Girders,—Effect of Impact, Vibratory Action, and Long Continued Changes of Load on Wrought Iron 16
———, Wood, (D. V.,) on General Problem of Trussed 97, 308
——— of one Arch,—Robinson, (S. W.,) Discussion of some Trussed 164
Grapes,—On Extracting the Juice from 52
Gun-cotton,—On the Chemical History and Applications of 37, 133, 189
Gunpowder,—Composition of a New Blasting 180
———— from Wood,—Process for Making 342

Haswell, (C. H.,) on Limes, Cements, Mortars, and Concretes, 361
Hot Air Engine,—Improvement in the 412
Hydrants and Fire Service, 81, 168, 236, 289
Hydraulic Cements, 407
———— Engineering. By S. McElroy, 81, 168, 236, 289
———— Jack,—Notice of Mr. Blackwood's 139
———— Pressure,—Joule's Method of Testing Steam Boilers by 180

Inch and the Metre as a Standard Unit of Decimal Measure,—On the Relative Advantages of the 176
Incrustations of Marine Boilers,—On the 30
Indian Ink,—Substitute for 51
Ink with Prussian Blue, On the Preparation of Blue 52
Iowa,—Particulars of the Iron Steamship 396
Iron Girder Bridge,—Description of the proposed Great 235
—— Girders,—On the Effect of Impact, Vibratory Action, and Long Continued Changes of Load on Wrought 16

Iron in Water,—On the Preservation of . . . 36
—— Ships,—On a Mode of Coppering . . . 51
—— Steam or Water Pipes,—On the Proportions of Cast . 276
—— Steamships,—Particulars of . . . 394
——, Thin Rolled 279

Kneass, (S.,) on the new Bridge over the Schuylkill River, . 413

Leaves of Plants,—On the Functions of the . . 408
Leveling and Surveying by means of a Visual Angle Rod, . 73
Light,—Cheap Form of Automatic Regulator of the Electric . 179
——— for Coal Mines,—New Safety . . . 262
———, On the Magnesian . . . 179
Limes, Cements, Mortars, and Concretes,—Haswell, (C. H.,) on . 361
Liquids,—Exposition on the late Researches on the Cohesion Figures of 209
Locomotives at Kensington,—The Historical . . 299
—————, Steel 399
Lowell Factories, Mass.,—On the Means for Extinguishing Fire in the 268
Lubricating Cup for Steam Engine Cylinders, &c.,—Notice of Shaw's 139
Magnesian Light,—On the 179
Magnet,—Description of a New Electro- . . . 406
Matches,—On the Composition of Japan . . . 109
Mayer, (J. R.,)—Essay on the Stadia, . . . 1
McElroy, (S.,)—Papers on Hydraulic Engineering, . 81, 168, 236, 289
Mechanical Power,—On Atmospheric Pressure as a Source of . 200
Metals,—On the Manipulation of . . . 34
Meteorological Observations in Philadelphia, 69, 144, 215, 288, 360, 427
Metre as a Standard Unit of Decimal Measure,—On the Relative Advantages of the Inch and the . . 176
Mortar in Southern Italy,—Description of the Mode of making . 125
Mortars, and Concretes,—Haswell, (C. H.,) on Limes, Cements, . 361
———,—W. Wallace, on Ancient . . . 409

Nystrom, (J. W.,) on Work and Vis-viva, . . 181
—————— on the Dynamometer at the Royal Technological Institute at Stockholm, . . . 392

Osborne, (J. W.,) Paper on a Practical Photographic Process and its Applications, ... 57
Oxygen,—On the Supposed Nature of Air before the Discovery of 194, 333, 404

Paddle-wheel,—Van Buren, Jr., (J. D.,) on the Radial . 32, 93
Paraffin for Waterproofing,—On the Employment of . . 340
——— as a Fuel for Propelling Steam Machinery,—Experiments on the Use of 129
——— as Steam Fuel in Place of Coal,—On the Use of . 130
Photographic Process and its Applications, Osborne, (J. W.,) Paper on a Practical . . . 57
Pipes and Roof Sheeting,—Bituminized Paper . . 210
—— with Faced Flange Joints,—Briggs, (R.,) on the Proportions of Cast Iron Steam or Water . . . 276
Plants,—On the Functions of the Leaves of . . 408
Plumb Line Deflection at Cowlythe,—Remarkable . . 25
Puddling by Machinery, ... 278
Pulpit and the Rostrum,—Bibliographical Notice of the . 426

Radiation of the Electric Light,—Tyndall on the Invisible . 390
Railway Trains,—The Construction, Traction, Retardation, Safety, and Police of 145, 226
————Working to Prevent Destructive Wear and Risk,—On the Mechanical Conditions of . . . 153, 217
Rain,—What is an Inch of . . . 256
Rains,—On the Fall of Heavy . . . 257
Reservoir,—Account of the Bursting of a . . . 298

Rivers,—The Catchment Basins of 367
Robinson, (S. W.,) on Leveling and Surveying by means of a Visual Angle and Rod, 73
———— on the Use of the Double Eye-piece in the determination of the Personal Equation. 385
———— Discussion of some Trussed Girders of one Arched Chord, 164
Rocks,—Mushet, (R.,) on a Steel Suitable for Boring 127

Saddle,—Description of a Useful Pack- 26
Science in the Witness Box, 110
Screw Threads, &c.,—Report of a Committee on a Uniform System of
————, R. Briggs on a Uniform System of 111
—— Propeller,—On the Invention of the 258
Sea Water at Different Depths and in Different Latitudes,—On the Constitution of 107
Ships,—On a Mode of Coppering Iron 51
——, Particulars of Iron Steam 394
——, Speed of 397
Springs,—Notice of U. B. Vidal's Car or Carriage 139
Stadia,—Mayer, (J. R.,) Essay on the 1
Steam Boiler Regulations in Paris,—The New 267
—— Boilers by Hydraulic Pressure,—On Joule's Method of Testing 180
————,—On the Facts and Fallacies as to the Tubular 377
————, On the Incrustation of Marine 30
—— Engines, Cylinders, &c.,—T. Shaw's Lubricating Cup for 139
—— ——, Description of Lake's Differential 329
—— Expansion,—Apparatus Prepared for the Experiments on 280
—— Machinery,—on the use of Petroleum as a Fuel for Propelling 129
——, On a New Formula for Calculating the Initial Pressure of 129
—— or Water Pipes,—On the Proportions of Cast Iron 274
——, On the Elastic Force of 371
Steel Bridge,—Description of a 298
Stone under Fire,—On the Value of 397
Sulphur on the Voltaic Battery,—On the Action of 411
Surface Condensers Superseded, 331
Surveying and Measuring by means of a Visual Angle and Rod, 73

Traveling,—On the Economy and Safety of Different modes of 263
Trompe,—Experiments on the 318

Van Buren, Jr., (J. D.,) on the Radial Paddle-wheel, 22, 93
Vis-viva,—Wood, (D. V.,) on Work and 27, 385
———— Nystrom, (J. W.,) on Work and 181
Voltaic Battery,—On the Action of Sulphur on the 411

Washington,—Particulars of the Iron Steamship 395
Water at Different Depths and in Different Latitudes,—On the Constitution of Sea 107
——, Method of Building under 295
—— Pipes with Faced Flange Joints,—On the Proportions of Cast Iron Steam or 276
—— Proofing.—On the Employment of Paraffin for 340
—— to Cities.—On the Supply of 45
Westminster,—Particulars of the Iron Steamship, 398
Wheel,—Van Buren, Jr., (J. D.,) on the Radial Paddle- 22, 93
Witness Box,—Science in the 110
Wood, (D. V.,) on Work and Vis-viva, 27, 385
———— on General Problem of Trussed Girders, 97, 308
——, Process for Making Gunpowder from 342
Work and Vis-viva,—D. V. Wood on 27, 385
————————J. W. Nystrom, on 181

Zinc,—On the Reduction of Aluminium by 178

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